R-2358/2-PA&E
April 1979

MANPOWER: A Model of Tactical Aircraft Maintenance Personnel Requirements, Volume II, Technical Appendixes

W. S. Furry, K. M. Bloomberg, J. Y. Lu, C. D. Roach J. F. Schank,

A Report prepared for

OFFICE OF THE ASSISTANT SECRETARY OF DEFENSE/ PROGRAM ANALYSIS AND EVALUATION

Rand
SANTA MONICA, CA. 90406

The research described in this report was sponsored by the Office of the Assistant Secretary of Defense/Program Analysis and Evaluation under Contract No. MDA903-77-C-0107.

Library of Congress Cataloging in Publication Data
Main entry under title:

Manpower, a model of tactical aircraft maintenance
personnel requirements.

([Report] - Rand Corporation ; R-2358-PA&E)
CONTENTS: v. 1. Overview of model development and application.--v. 2. Technical appendixes.
1. United States. Air Force--Aviation mechanics.
2. Airplanes, Military--Maintenance and repair--Mathematical models. 3. Airplanes, Military--Maintenance and repair--Data processing. 4. MANPOWER (Computer program)
I. Furry, W. S., 1945- II. United States. Assistant Secretary of Defense (Program Analysis and Evaluation). III. Series: Rand Corporation. Rand report ; R-2358-PA&E.

AS36.R3 R-2358 [UG1133] 81s [355.2'2] 79-11617
ISBN 0-8330-0107-8 (v. 2)

Published by The Rand Corporation

R-2358/2-PA&E

April 1979

MANPOWER: A Model of Tactical Aircraft Maintenance Personnel Requirements, Volume II, Technical Appendixes

W. S. Furry, K. M. Bloomberg, J. Y. Lu, C. D. Roach J. F. Schank,

A Report prepared for

OFFICE OF THE ASSISTANT SECRETARY OF DEFENSE/ PROGRAM ANALYSIS AND EVALUATION

Rand
SANTA MONICA, CA. 90406

PREFACE

This volume contains supporting documentation for MANPOWER, a PL/I computer model for predicting the base-level maintenance personnel requirements of prospective aircraft in the Tactical Air Command, United States Air Force. Volume I in this two-volume set of reports provides an overview of the operation, composition, and application of the model.* The present set of technical appendixes supplies detailed procedures for determining work center requirements, as well as data bases used to develop and validate the model. Technical documentation of the computer program is available upon request, including an index of variables, a map of subroutines, a dictionary of subroutines and variables, and a program listing.

---

* *MANPOWER: A Model of Tactical Aircraft Maintenance Personnel Requirements, Volume I, Overview of Model Development and Application*, W. S. Furry, K. M. Bloomberg, J. Y. Lu, C. D. Roach, and J. F. Schank, The Rand Corporation, R-2358/1-PA&E, April 1979.

CONTENTS

TABLES

Appendix A

SIMULATION MANNED WORK CENTERS

The traditional approach in the calculation of maintenance personnel requirements has been to determine the workload (expressed in manhours per month) and divide this by the number of hours per month that a mechanic will be available for work. The problem with this method is that it fails to link the maintenance capability with operational performance. In response to this weakness, the Air Force has adopted a simulation technique (known as the Logistics Composite Model--LCOM) for maintenance personnel planning, which allows the analyst to determine the minimum work center manning required to guarantee the accomplishment of performance goals as measured by the sortie generation rate.

LCOM studies have revealed that the relationship between workload and optimal manning in an aviation maintenance work center is complex. Among the most important factors contributing to this complexity are the tendency of maintenance demands to occur simultaneously with the possibility of queueing, the need to guarantee minimum crew size, the existence of shift requirements, and the occurrence of incremental crew requirements.

The potential for queueing of maintenance demands is particularly great in a few large shops where the workload tends to cluster during peak flying periods. If extra personnel are not available at these times, a backlog of work will build up and the sortie rate goal will not be met. In these shops, the peak workload determines the manning requirement and personnel are underutilized compared with other work centers in which the workload can be deferred.

Minimum crew sizes, incremental crew sizes, and shift requirements have a less dramatic effect on manning than the density of maintenance demands, but they contribute to the variation in personnel requirements of various work centers:

- In shops that are minimum manned, the workload often can double or triple without affecting the personnel requirement. Two shops with the same minimum manning easily could have different workloads; and two shops with the same manhour workload could have different minimum crew sizes.
- The personnel requirement for an additional increment of work (a number of manhours) depends on the crew size needed to perform the additional tasks. Crew sizes range from one (in all shops) to six (on the flight line) and crews of two and three are common in many shops.
- For a given workload, differences in the shifts that must be covered can produce different personnel requirements. If the shop is manned at the minimum crew size, the requirement is a multiple of the number of shifts that must be covered. In shops where the workload exceeds the capacity of a minimum crew, the impact of shift requirements depends on the extent to which work can be deferred and on crew size requirements.*

LCOM enables the analyst to address the interaction of these factors in determining the personnel requirements in maintenance work centers. However, LCOM requires detailed data on component reliability and maintainability and considerable analysis to accurately model the sequence of tasks involved in scheduled and unscheduled maintenance. These detailed data are not available early in the weapon system acquisition process. Furthermore, accumulating the necessary information at later stages in system development is a time-consuming and expensive process.

---

*For example, assume that a shop has 24 manhours of work on one shift that must be performed by crews of two and that cannot be deferred to another shift; for simplicity we will assume that each mechanic can work eight productive hours per day. On this shift, then, four workers would be required (two people could produce 16 hours of work; another full team is needed for the remaining eight hours). If a second shift must be covered, two more mechanics will be required (even if the workload is light) for a total of six. If the workload on the second shift were less than eight hours, and if the work on the first shift could be deferred, then four workers could handle the entire job instead of six (for the same total workload).

Our objective has been to develop a simple model of the LCOM that captures the major features of the workload-manning relationship in the various work centers. We have used linear regression techniques to analyze the results of seven LCOM studies to derive a set of predicting equations for those work centers where requirements are determined by simulation. In the following subsections, the data and procedures in this analysis are discussed.

LCOM DATA

The results of LCOM analyses of the personnel requirements for the F-111D, A-7D, RF-4C, F-4E (1973), F-4E (1978), A-10, and F-16 were available for this study.* The data base is listed in Appendix E.

In their simulation studies, TAC analysts varied the deployment size (UE) to determine requirements for one, two, or three squadrons. In addition, for the F-4E (1978) LCOM analysis, TAC researchers also varied the sortie rate within deployment sizes. The total number of simulations in the LCOM data base for the present analysis was 30, broken down as shown in Table A.1.

In each of the 30 studies, LCOM simulates the maintenance activity in the work centers for which manning is to be determined. The set of work centers simulated for the newer aircraft is slightly

---

*These studies were used: *Final Report TAC Manpower Standards A-7D FC22XX, 23XX, 24XX Computer Simulated Wartime Manning Requirements*, 4400 Maintenance Engineering Squadron, Langley Air Force Base, Virginia, 18 June 1976; *Final Report TAC Engineered Manpower Standards RF-4C FC22XX, 23XX, 24XX Computer Simulated (LCOM) Wartime Manning Requirements*, 4400 Maintenance Engineering Squadron, Langley Air Force Base, Virginia, August 1975; "F-4E Logistics Composite Model Study," study conducted by TAC Headquarters, Directorate of Manpower and Organization, August 1973; *Final Report TAC Statistical Manpower Standard F111A/D/F Computer Simulated Wartime Manning Requirements*, 4400 Maintenance Engineering Squadron, Langley Air Force Base, Virginia, 30 June 1976. Results of the A-10 and F-4E (1978) LCOM studies were obtained in unpublished form from the Directorate of Manpower and Organization, TAC Headquarters, Langley Air Force Base, Virginia. Results of an October 1976 LCOM study for the F-16 were obtained from the project office, Wright-Patterson Air Force Base, Ohio. The first version of the model was developed using the F-4E (1973) study. The second version (following the validation described in Appendix D) used the F-4E (1978) study and the 1973 study was dropped. The statistics reported in this appendix also exclude the 1973 study.

Table A.1

BREAKDOWN OF LCOM SIMULATIONS
USED IN THIS STUDY

Aircraft Type	Deployment Sizes (UE)	Achieved Sortie Rates
A-7D	24,48,72	.87
A-10	24	.90
	48	.93
F-111D	24,48	.70
RF-4C	18,36,54	.67
F-4E(1973)	24,48,72	.96
F-4E(1978)	18	.70,.90,1.02
	24	.64,.98,1.18
	36	.73,1.01,1.21
	48	.76,1.11,1.22
	72	.74,1.06,1.36
F-16	24	.98
	48	1.00

different from those of earlier aircraft, as illustrated in Table A.2. For the F-4E (1973), 18 work centers are simulated for deployments of 24, 48, and 72 UE; thus, there are 54 (3 x 18) work center simulations in total for this F-4E study. Similarly, there are 54 cases for the A-7D, 51 for the RF-4C, 24 for the F-111D, 28 for the F-16, and 44 for the A-10. The F-4E (1978) study involved 15 simulations of 26 work centers for a total of 390 cases. Overall, the data base consists of 645 simulated work centers. Looking at the rows in Table A.2, we can determine, for example, that there are 30 cases for Flight Line Maintenance, 26 cases for Machine Shop, 28 cases for Automatic Flight Control, and four cases for Automatic Test Stations.

The essential information associated with each case in the data set is:

1. Work center code
2. Aircraft type

Table A.2

WORK CENTERS MANNED BY LCOM FOR VARIOUS AIRCRAFT

	Aircraft Mission/Design/Series							Total Number of Cases
Work Center	F-4E (1973)	F-4E (1978)	A-7D	RF-4C	F-111D	F-16	A-10	
Organizational Maintenance								
Flight Line Maintenance	x	x	x	x	x	x	x	30
Inspection	x	x	x	x	x	x	x	30
Field Maintenance								
Machine Shop	x	x	x	x	-	-	x	26
Metal Processing	x	-	x	x	-	-	-	9
Structural Repair	x	x	x	x	x	x	x	30
Fuel Systems	x	x	x	x	x	x	x	30
Electrical Systems	x	x	x	x	x	x	x	30
Pneudraulics	x	x	x	x	x	x	x	30
Environmental Systems	x	x	x	x	x	x	x	30
Egress Systems	x	x	x	x	x	x	x	30
Repair and Reclamation	-	x	-	-	-	-	x	17
Jet Engine	x	x	x	x	x	x	x	30
Avionics Maintenance								
Radio	x	x	x	x	-	-	x	26
Radar	x	x	x	x	-	-	x	26
Doppler-Inertial Navigation	x	x	x	x	-	-	-	24
Automatic Flight Control	x	x	x	x	-	x	x	28
Instruments	x	x	x	x	-	-	x	26
Integrated System Fire Control	x	-	x	-	-	-	-	15
Photo Reconnaissance	x	x	x	x	-	-	x	26
Sensors	-	-	-	-	-	-	x	2
Flight Line Avionics	-	-	-	-	x	-	-	2
Automatic Test Stations	-	-	-	-	x	x	-	4
Manual Test Stations	-	-	-	-	x	-	-	2
Avionics AGE	-	-	-	-	-	x	-	2
Weapons Control-Inertial Navigation	-	x	-	-	-	x	x	25
Communication-Navigation-Penetration Aids	-	-	-	-	-	x	-	2
Electronic Warfare	-	x	-	-	-	-	x	17
Munitions Maintenance								
Weapons Loading	-	-	-	-	-	-	x	17
Weapons Release	-	x	-	-	-	-	x	17
Gun Services	-	x	-	-	-	-	x	17
Missile Maintenance	-	x	-	-	-	-	-	15
Storage and Handling	-	x	-	-	-	-	-	15
Munitions Maintenance	-	x	-	-	-	-	-	15
Total Number of Cases	54	390	54	51	24	28	44	645

3. Deployment size (number of aircraft)
4. Personnel requirements
5. Maintenance manhours
6. Achieved sortie rate

The *personnel requirement* is the total number of authorizations that should be allocated to the work center for operation in a wartime environment. The requirement is based on the assumption that an individual is available 242 hours a month for indirect and direct maintenance work. If the LCOM simulation is valid, the requirement guarantees accomplishment of the sortie rate goal.

Calculation of the personnel requirement by LCOM proceeds as follows for each work center: The LCOM is exercised several times for a given deployment until the minimum manning is found that maintains the sortie rate goal (defined below). Since the LCOM methodology (in most studies) assumes that mechanics work 12 hours per day, seven days per week, the LCOM "constraining" personnel requirement must be translated to a requirement based on actual expectations for a mechanic's workday (this is ten hours per day, six days per week during war). Thus, the LCOM manning is multiplied by a factor (1.5099) to determine the actual personnel requirement (which is used in the analyses presented in this report).

Maintenance manhours is the total manhours of workload generated during the simulation run (usually between 60 and 180 days of simulated wartime flying). This value can be divided by the achieved flying hours or sorties to determine maintenance manhours per flying hour or per sortie (MMH/FH or MMH/S). MMH/S is the measure used in the prediction equations incorporated in MANPOWER. In the following pages, the terms *manhours* and *total manhours* (when not followed by *per flying hour* or *per sortie*) are used interchangeably to refer to the *total workload* in a shop for a thirty day period (this equals the total manhours generated during a simulation run divided by the number of thirty day periods in the simulation).

The *achieved sortie rate* is the wartime goal for the number of sorties to be flown per aircraft per day. In an LCOM study, manning in the work centers is adjusted across shifts on several simulation runs until the minimum level is found that just maintains this required sortie rate. The achieved sortie rate equals about 90 percent of the wartime programmed sortie rate (thus, 10 percent of the scheduled sorties may be aborted).

In the analysis, we discovered that the manning for communication-navigation-penetration (CNP) aids for the F-16 was inordinately high compared with the requirements for other work centers with similar workloads. We also learned that manning for electronic countermeasure (ECM) pods (a standard manned shop) was included in the CNP requirement. However, we could not determine precisely how many extra personnel were included in this requirement; therefore, the F-16 CNP work center was eliminated from subsequent analyses.

ANALYSIS OF LCOM SHOPS

The analysis objective was to specify a set of equations to predict the maintenance personnel requirements in work centers currently manned by LCOM simulation. We assumed that an estimate of the workload (in manhours per flying hour or per sortie) for groups of work centers and for several of the large individual work centers would be available early in the acquisition process. This assumption was based on the observation (made during a survey of the personnel planning procedures in the Army, Navy, and Air Force) that maintenance workload goals conventionally are established during the concept development stage of weapon system acquisition. These goals combine a rough assessment of the current state of the art in reliability and maintainability with hoped for improvements over the weapon system being replaced.

The following discussion is in two parts. First, we consider how the LCOM shops might be aggregated. This is necessary because it is unlikely that maintenance manhour goals will be set for every individual shop; it is more realistic to set goals for functional

areas such as Jet Engine, Aerospace Systems, and Avionics.* In the second part, we accept the shop categories as determined and attempt to find a best equation for each category. In that analysis, we consider the influence of sortie rate and organizational size on the personnel requirement.

It is often difficult to determine which of several alternative work center groupings or estimating equations is best when they must be judged by multiple criteria. Usually one solution does not dominate all others. The criteria that guided this search for a set of predicting equations are set forth at the beginning of each of the two following subsections.

Levels of Aggregation

Two potential conflicting concerns are paramount in the choice of work center groups. First, we want to recognize significant differences among the work centers in their utilization rates. But second, the work center groupings must also be consistent with the scope of the maintenance workload goals that are the principal inputs to the manning equations.

---

*The original version of MANPOWER was designed under the assumption that the workload estimates for the prospective aircraft would be gross and highly aggregated. This premise led to the specification (described in this appendix) of four work center groups for which the model user was to supply MMH/FH.

Subsequently, the desire to assess the impact of changes in reliability and maintainability on personnel requirements resulted in the development of new input options for the model. The user can now supply mean-time-between-failures and mean-time-to-repair (MTBF and MTTR) in 37 second-digit work unit code categories. Nevertheless, the model still uses four basic equations to predict personnel requirements in 15 to 20 LCOM shops by aggregating the reliability and maintainability data to the four work center group level. Additional research might be undertaken to develop unique equations for each LCOM work center that would be applied when the user inputs detailed reliability and maintainability data. If individual work center equations are incorporated in the model, then the four work center group equations described in this appendix would be applied only when the user inputs maintenance workload estimates in terms of MMH/FH in the four work center areas or in terms of MMH/S in the seven first-digit work unit code categories.

It can be seen in Table A.2 that there are 12 to 25 LCOM simulated work centers in aircraft maintenance. There are three extreme approaches to the aggregation of these work centers. The first is no aggregation at all; each work center is treated individually. Table A.3 displays the least squares linear relationships between manning and total workload for the individual work centers. The reciprocal of the slope (1/B) will be called the "utilization rate"; it represents the average number of hours of workload per month per mechanic.

Another extreme approach is to derive a single equation that can be applied to all work centers. In this case, total manning is equal to the constant term in the equation multiplied by the number of shops, plus total workload divided by the utilization rate. Table A.3 shows the equation that was derived from the total sample of 464 work centers.

The third extreme is to consider total manning over all work centers and to derive an equation for this total. In this approach, the LCOM shops are treated as if they were essentially one work center with a single utilization rate. Table A.3 displays the results of the analysis of total manning for 27 deployments.

Each of these extreme approaches has its problems. Individual equations for each work center would require that MMH/FH goals be specified at the work center level for all work centers. It seems unrealistic to require planners to specify the maintenance goals at this level of detail in the concept development stage of system acquisition. Some aggregation of work centers is necessary.

The second approach--one equation for all work centers--fails to address the different utilization rates for various work centers. As a result, with this equation the analyst could not examine the differential impact on manning of changes in the workload in major work centers or in groups of work centers. Similarly, the third equation, which relates total manning across all work centers to the workload, is insensitive to the range of utilization rates.

These considerations led us to explore possible groupings of the work centers and to examine combinations of the extreme approaches.

Table A.3

LEAST SQUARES LINEAR RELATIONSHIP BETWEEN MANNING AND WORKLOAD IN LCOM MANNED WORK CENTERS

Work Center	N	a	b	Personnel Utilization Rate (1/b)	R^2
Organizational Maintenance					
2110 Flight Line Maintenance	27	2.27	.00726	137.7	.94
2120 Inspection	27	5.45	.00565	177.0	.93
Total	27	13.42	.00652	153.4	.95
Propulsion					
2323 Jet Engine Shop	27	2.68	.00703	142.2	.97
Aerospace Systems and Structural Repair					
2313 Structural Repair	27	1.08	.00701	142.7	.98
2334 Pneudraulics	27	2.57	.00628	159.2	.94
2333 Electrical Systems	27	2.16	.00626	159.7	.92
2332 Fuel Systems	27	3.56	.00604	165.6	.93
2336 Environmental Systems	27	3.46	.00540	185.2	.93
2331 Repair and Reclamation	17	11.14	.00490	204.1	.80
2339 Egress Systems	27	6.49	.00276	362.3	.43
Average	179	3.51	.00627	159.5	.95
Avionics Maintenance					
F-4E, A-7D, A-10, RF-4C					
2435 Sensors	2	5.00	0.0	--	--
2432 Weapons Control	20	.61	.00710	140.8	.99
2413 Electronic Warfare	17	.45	.00707	141.4	.98
2411 Radio	23	1.00	.00694	144.1	.97
2422 Instruments	23	1.97	.00622	160.8	.93
2414 Doppler Inertial Navigation	21	2.51	.00563	177.6	.92
2434 Photo Reconnaissance	23	3.62	.00502	199.2	.98
2421 Automatic Flight Control	23	3.87	.00460	217.4	.66
2412 Radar	23	4.00	.00423	236.4	.88
24XX ECM End of Runway	15	5.28	.00190	526.3	.47
Average	190	2.25	.00642	155.8	.97
F-111D, F-16					
2461 Avionics Aerospace Ground Equipment	2	6.00	0.0	--	--
2463 Manual Test Stations	2	13.97	.01080	92.6	--
2462 Automatic Test Stations	4	-2.09	.01136	88.1	.98
2436 Weapons Control	2	3.10	.00624	160.4	--
24XX Flight Line Avionics	2	20.91	.00677	147.7	--
2433 Automatic Flight Control	2	6.00	.00281	355.9	--
Average	14	8.33	.00781	128.0	.96
All Work Centers	464	3.73	.00743	134.6	.79
Total Manning (sum of shops within each deployment)	27	57.14	.00655	152.7	.95

SOURCES: Various LCOM studies. Excludes F-4E (1973), Machine Shop, Metal Processing, CNP aids, and Munitions Maintenance LCOM manned work centers shown in Table A.2.

It seemed reasonable to consider the three maintenance squadrons (Organizational, Field, and Avionics) separately because of the functional differences between them and the relatively simple process of dividing total MMH/FH goals into these three broad areas.

Organizational Maintenance. LCOM manned work centers in the Organizational Maintenance Squadron are Flight Line Maintenance and Inspection.* Flight Line Maintenance is the largest single work center in aircraft maintenance and its manning is determined by peak workload requirements. Because of the size of this activity (a wing may have more than 200 flight line mechanics) and its central role in support of the aircraft, it is appropriate to develop an individual estimating equation for this work center. In addition, MMH/FH goals are normally specified for this function.

The Inspection activity is a relatively small work center, employing roughly 8 to 30 mechanics for 18 to 72 aircraft. Personnel requirements for Inspection depend largely on policies governing the frequency of inspection. The greater the frequency of inspection, the larger the requirement. Since these policies normally are not stipulated early in the acquisition decisionmaking process, it is not reasonable to use an individual equation for Inspection in MANPOWER.

It was decided to sum Inspection and Flight Line and develop one equation for the total LCOM manning of Organizational Maintenance. Table A.3 displays the relationship between manning and workload for this total.

Field Maintenance. The Field Maintenance Squadron includes ten LCOM manned shops compared with two in Organizational Maintenance; but the total LCOM personnel requirements of the two squadrons are often fairly close.

---

*Support Equipment and Overhead and Supervision are manned using traditional operational audit and statistical techniques. Base Flight Aircraft Maintenance and Transient Aircraft Maintenance requirements are determined by statistical standards (however, they are not included in MANPOWER because these requirements are substantially independent of the support requirements of the primary weapon system).

LCOM simulated Field Maintenance shops include three in Fabrication (Metal Processing, Machine Shop, and Structural Repair), one in Propulsion (Jet Engine), and six in Aerospace Systems (Repair and Reclamation, Fuel Systems, Electrical Systems, Pneudraulics, Environmental Systems, and Egress Systems). In contrast with the Avionics Squadron where each new aircraft in recent time has had a unique set of shops, the structure of Field Maintenance has not changed in recent years with the introduction of new aircraft. All ten shops are found in the maintenance organizations of the six diverse weapon systems in this analysis.

Our analysis suggests a simple grouping for the Field Maintenance LCOM shops: Jet Engine Shop will stand alone; Machine Shop and Metal Processing will be treated individually because both are usually minimum manned; and the Aerospace Systems Shops and Structural Repair will form a third group.

Because both shops have extremely light workloads, Machine Shop and Metal Processing are often minimum manned. Realizing this, the analysts who performed the F-111 and F-16 LCOM studies did not include these shops in their simulations. The requirements in Machine Shop and Metal Processing depend in large part on the shifts that must be covered and on the minimum crew sizes per shift. Table A.4 shows the requirements for the six weapon systems. There is no simple rule that explains the manning in these work centers.

Probably the best way to generalize the manning of Machine Shop and Metal Processing is to relate the requirement to the aircraft mission, which usually is closely connected with the number of shifts to be covered. However, the F-16 requirement is surprisingly low compared with that of the F-4. It is not unlikely that this estimate (which was not simulated) for the F-16 is overly optimistic and reflects a desire to present the maintenance requirements of this emerging system in a favorable light. In MANPOWER, the requirements for Machine Shop and Metal Processing are calculated as shown in Table A.5. These requirements are rough averages, based on the data exhibited in Table A.4.

Table A.4

MANNING REQUIREMENTS IN MACHINE SHOP AND METAL PROCESSING
FOR VARIOUS DEPLOYMENT SIZES[a]

Mission/ Design/ Series	Machine Shop						Metal Processing					
	UE						UE					
	18	24	36	48	54	72	18	24	36	48	54	72
F-4E(1973)		6		6		6		2		2		3
F-4E(1978)[b]												
1.02	6						6					
.90	6						6					
.70	6						6					
1.18		6						6				
.98		6						6				
.64		6						6				
1.21			6						6			
1.01			6						6			
.73			6						6			
1.22				7						6		
1.11				6						6		
.76				6						6		
1.36						11						6
1.06						9						6
.74						6						6
A-7D		5		5		5		5		5		5
RF-4C	2		2		2		2		2		2	
F-111D		3		5				3		6		
F-16		2		3				2		3		
A-10		2		2				3		7		

SOURCES: Various LCOM studies.

[a]Requirements are established for a particular scenario; they may vary under different operational assumptions.

[b]Requirements are for the sortie rates listed in the table.

Table A.5

CALCULATION OF REQUIREMENTS FOR MACHINE SHOP AND METAL PROCESSING IN MANPOWER

1. If the new aircraft has a reconnaissance mission, the manning for each deployment unit will be:
    a. Machine Shop = 2
    b. Metal Processing = 2
2. If the new aircraft does not have a reconnaissance mission, then manning for each deployment unit will be:
    a. Machine Shop = 6
    b. Metal Processing = 4

The manning of each deployed unit is determined separately and the peacetime base manning is equal to the sum of the separate deployment requirements. Thus, the total for Metal Processing and Machine Shop for a fighter wing of three squadrons deploying two-ways would equal 20 (6 + 6 + 4 + 4).

The next major subdivision of Field Maintenance is the Propulsion branch, which now is limited to the Jet Engine Shop. It seemed reasonable to develop a separate estimating equation for this shop because of its size and because there is a good chance MMH/FH goals will be stipulated for jet engine maintenance in the early phases of system acquisition.

The simple relationship between manning and total manhours in the Jet Engine Shop is shown in Table A.3. In our analysis, the Jet Engine Shop requirement includes the personnel needed in the test cell. In a later section, we will refine this estimating equation by introducing variables for the density of the flying program (the sortie rate) and the deployment unit size.

We turn now to the shops in the Aerospace Systems branch. Structural Repair (which is actually part of the Fabrication branch) will be included in this analysis because its manning is much like that of the Aerospace Systems Shops: It has crew sizes of

one and two, the workload normally exceeds minimum manning requirements, and the work can be deferred so that peak manning is not necessary. Table A.3 has shown the individual linear relationships between manning and manhours for the seven shops under consideration.

The ideal approach would be to develop a best estimating relationship for each shop. However, it is unlikely that maintenance manhour data will be available for each of these shops during the concept development phase of system acquisition. Consequently, we will develop an equation based on the assumption that a total workload estimate (in terms of MMH/FH or MMH/S) for the Aerospace System Shops and Structural Repair will be available for use in MANPOWER.

Since we will have only *total* MMH/S for seven shops, we can employ only one equation (that is, one utilization rate). This will not be a significant weakness in the model if, in fact, the utilization rates for the seven shops are the same or very close. Statistical tests were performed on the slopes of the work center regression equations to determine whether any of the utilization rates were significantly different from the others. If we found one or several that were different, we would want to consider ways to develop individual equations.

Table A.6 displays the results of the one-way anova F-tests of slopes (utilization rates) of the seven shops under consideration. The utilization rates appear to be quite heterogeneous for this set of work centers. Only Pneudraulics, Electrical Systems, and Fuel Systems form a homogeneous subset. Egress Systems, Repair and Reclamation, and Environmental Systems have relatively high utilization rates because, in shops like these, which are usually minimum manned, a relatively large increase in workload is required to generate an increase in the personnel requirements.

In sum, the statistical analysis suggests using separate equations for four individual work centers and one for a group of shops. However, as previously indicated, since data will usually not be available separately for each of these shops, an average equation for these work centers is incorporated in MANPOWER. The average relationship between manning and manhours is shown in Table A.3.

Table A.6

COMPARISON OF UTILIZATION RATES IN AEROSPACE SYSTEMS AND STRUCTURAL REPAIR WORK CENTERS

Work Center	Slope (B_i)	$\hat{\sigma}B$	One-Way Anova F-Tests for Groups of Work Centers					
2313 Structural Repair	.00701	.00018	x	x				
2334 Pneudraulics	.00628	.00031	x	x	x	x		
2333 Electrical Systems	.00626	.00036	x		x	x		
2332 Fuel Systems	.00604	.00034	x		x	x		
2336 Environmental Systems	.00540	.00030	x			x	x	
2331 Repair and Reclamation	.00491	.00064	x				x	x
2339 Egress Systems	.00276	.00064	x					x
Weighted Mean ($\bar{B}$):			.00626	.00683	.00620	.00596	.00531	.00384
$\Sigma Z^2 = [(B_i - \bar{B})\hat{\sigma}B]^2$:			60.35	4.15	.32	5.29	.48	5.64
Probability of ΣZ^2 this large if B_i are the same:			< .01	< .05	> .80	< .20	< .50	< .01

<u>Avionics Maintenance</u>. The aggregation of the LCOM manned Avionics Maintenance Shops presents problems similar to those encountered with the Aerospace Systems; but in addition, we must be concerned with the reorganization of these shops that has occurred with the introduction of new weapon systems. Table A.2 shows the Avionics work centers that have been simulated for the six weapon systems included in this analysis. Table A.3 shows the individual work center equations.

The upheaval in the organization of avionics maintenance, which is exemplified by the differences between the F-111D and the F-16 and between these aircraft and the A-7D, A-10, F-4E, and RF-4C, can be linked to the introduction of increasingly integrated avionics. The new avionics have changed the tasks performed by mechanics, changed the crew size requirements, and altered the relationship between avionics specialists and the ability of the wing to generate sorties. Now, since the functional areas of avionics are much more interdependent than in traditional systems, the likelihood that a sortie will have to be aborted if an avionics subsystem fails has increased because of the difficulty in identifying the source of the failure. In the past, a component failure might not require cancellation of a particular mission; but now, to isolate the failure, the entire avionics system often must be simulated.

We hypothesized that one consequence of the changes that have been occurring in Avionics Maintenance would be a reduction in the utilization rate of personnel. This idea is borne out, first of all, in the manning of the CNP aids work center of the F-16; this is the only avionics shop where manning has been dominated by the peak workload requirements.*

---

*As noted previously, the CNP aids work center is not included in the regression analyses discussed here because the data given to us included an unspecified number of non-LCOM personnel. The information that CNP is peak-manned was provided by Lt. James Lowell who participated in the F-16 LCOM analysis at Headquarters, Aeronautical Systems Division, Wright-Patterson Air Force Base.

Statistical tests were conducted comparing the personnel utilization rate in the maintenance of "integrated" avionics (F-16, F-111D) with that for "nonintegrated" avionics (F-4E, RF-C, A-10, A-7D). Table A.7 shows that the utilization rate is higher in the maintenance of the older systems, and this difference is statistically significant at the .01 level. This is further evidence supporting the hypothesis that "integrated" systems have reduced the utilization rates in Avionics Maintenance.* It is not unreasonable, then, to argue that different equations should be used in MANPOWER to determine the personnel requirements in shops that maintain "integrated" and "nonintegrated" avionics.

Since there are only two cases for each avionics shop for the integrated weapon systems (except for Automatic Test Stations, which has four--see Table A.2), we cannot analyze the homogeneity of the utilization rates among these shops. However, this analysis can be performed for the traditional aircraft (see Table A.8).

The analysis suggests that there is considerable variation between avionics work centers in their personnel utilization rates. Only three shops form a subset where it is likely the shops have the same or nearly identical utilization rates (Weapons Control, Electronic Warfare, and Radio). ECM End of Runway is minimum manned, which accounts for its high utilization rate. At some time in the future development of MANPOWER, individual equations for these avionics shops should be incorporated as an option in the model. At present, the model differentiates only between "integrated" and "nonintegrated" avionics.

---

*It must be reemphasized that the personnel requirements as determined in an LCOM simulation are a function of the scenario and may change with a different scenario. In particular, the level of the spares inventory can influence the avionics personnel requirement. The greater the inventory, the easier it is to schedule (i.e., defer) the repair of broken components; hence, a greater investment in spares can eliminate the need for extra personnel during peak periods of demand for components.

Table A.7

ONE-WAY ANOVA F-TEST OF THE UTILIZATION RATES IN NONINTEGRATED AND INTEGRATED AVIONICS WORK CENTERS

Work Centers	Slope of Linear Regression (B_i)	Utilization Rate (hr) $(1/B_i)$	$\hat{\sigma}B$	$B_i-\bar{B}$[a]	Z^2[b]
Nonintegrated Avionics (F-4E, A-7D, RF-4C, A-10: N = 190)	.00642	155.8	.00009	-.00005	.31
Integrated Avionics (F-111D, F-16: N = 14)	.00781	128.0	.00045	.00134	8.87
					9.18
					6.635[c]

NOTES: [a] $\bar{B}$ = .00647; [b] $Z^2 = [(B_i - \bar{B})/\hat{\sigma}B]^2$; [c] $\chi^2_{1,.01}$ = 6.635.

Summary. This analysis has produced the following groups of LCOM manned work centers for separate treatment in MANPOWER.

- Machine Shop
- Metal Processing
- Organizational Maintenance
- Jet Engine Shop
- Aerospace Systems and Structural Repair
- Integrated Avionics
- Nonintegrated Avionics.

Because so few Munitions Maintenance work centers have been simulated (see Table A.2), we decided to determine these requirements in MANPOWER using the traditional work center standards (see pp. 43-52).

In the following subsection, we examine the development and refinement of the estimating equations for the LCOM manned work centers (excluding the machine and metal shops).

Table A.8

COMPARISON OF UTILIZATION RATES IN AVIONICS WORK CENTERS OF THE F-4E, A-7D, A-10, AND RF-4C

	Work Center	Slope (B_i)	$\hat{\sigma}B$	One-Way Anova F-Tests for Groups of Work Centers							
2432	Weapons Control	.00710	.00016	x	x						
2413	Electronic Warfare	.00707	.00024	x	x						
2411	Radio	.00694	.00025	x	x	x					
2422	Instruments	.00622	.00037	x		x	x				
2414	Doppler Inertial Navigation	.00563	.00038	x			x	x			
2434	Photo Reconnaissance	.00502	.00017	x				x	x		
2421	Automatic Flight Control	.00460	.00072	x					x	x	
2412	Radar	.00423	.00034	x						x	x
2403	ECM End of Runway	.00190	.00056	x							x
			Weighted Mean ($\bar{B}$):	.00608	.00706	.00671	.00593	.00512	.00500	.00430	.00360
			$\Sigma Z^2 = [(B_i - \bar{B})\hat{\sigma}B]^2$:	199.46	.29	2.60	1.23	2.15	.32	.21	12.65
			Probability of ΣZ^2 this large if B_i are the same:	< .01	> .80	< .20	< .30	< .20	> .50 < .70	> .50 < .70	< .01

Specification of the Manning Equations

The next step in this study was to specify the manning equations to be incorporated in MANPOWER for each of the work center groups identified in the previous section.

Data were available from the LCOM studies for three of the factors that we hypothesized to be most important in determining personnel requirements. These were:

- Workload. The total manhour workload in a shop was available; also, these data could be transformed to either MMH/S or MMH/FH. Notwithstanding the role of other factors in the determination of personnel requirements, the workload generated during the flying period is by far the most important determinant of personnel needs.
- Sortie rate. The achieved sortie rate in the LCOM simulation can be used as a measure of the density of the workload. That is, the greater the number of aircraft that must fly each day, the greater the number of tasks (usually scheduled tasks), that must be performed simultaneously; hence, the greater the personnel requirement.
- Deployment unit size. When the workload is expressed in terms of MMH/S or MMH/FH, a measure of unit size (UE) is required because size is a critical factor in the determination of the total workload.

Several alternative formulations of the prediction equations were examined for each of the work center groups. Tables A.9 to A.13 display some of these equations, the pertinent statistics, and the equations selected for inclusion in MANPOWER.

The reader will observe that in all groups several of the equations are about equally attractive in terms of the standard measures of fit: the coefficient of determination (R^2), the standard error of the estimate (SEE), the F-ratio (shown only for the selected equation), and the significance of the coefficients. It was decided

Table A.9

ALTERNATIVE FORMULATIONS OF THE RELATIONSHIP BETWEEN MANNING AND SELECTED INDEPENDENT VARIABLES IN ORGANIZATIONAL MAINTENANCE
(Flight line plus inspection)

Equation Form	Constant	Coefficients of Independent Variables				
		MMH/S	Sortie Rate	UE	R^2	SEE
Linear	-158.70	5.4875	114.00	2.1584	.93	13.6
Power	0.4701	0.9338	1.0799	0.8488	.97	8.9
Exponential	2.1988	0.0539	0.9667	0.0192	.95	11.8
Log-Linear**	-0.34942	0.8240	1.0378	0.8125	.95	.11

NOTES: N = 27; all coefficients are significant at .001 level; equation 4 F-statistic = 141.95, level of significance = > .99; **indicates equation incorporated in MANPOWER.

Table A.10

ALTERNATIVE FORMULATIONS OF THE RELATIONSHIP BETWEEN MANNING AND SELECTED INDEPENDENT VARIABLES IN THE JET ENGINE SHOP

Equation Form	Constant	Coefficients of Independent Variables				
		MMH/S	Sortie Rate	UE	R^2	SEE
Linear	-123.73	6.7614	96.042	1.1518	.89	13.0
Power	0.4273	0.8233	1.2135	0.9183	.98	5.0
Exponential	0.9795	0.13864	1.2744	0.0194	.96	8.17
Log-Linear**	-0.5376	0.81638	1.337	0.8380	.96	.14

NOTES: N = 27; all coefficients significant at the .001 level; equation 4 F-statistic = 170.63, level of significance = > .99; ** indicates equation incorporated in MANPOWER

Table A.11

ALTERNATIVE FORMULATIONS OF THE RELATIONSHIP BETWEEN MANNING AND SELECTED INDEPENDENT VARIABLES IN AEROSPACE SYSTEMS AND STRUCTURAL REPAIR

Equation Form	Constant	Coefficients of Independent Variables			R^2	SEE
		MMH/S	Sortie Rate	UE		
Linear	-19.442	6.2283	16.586	0.2143	.70	5.25
Power	0.6632	0.8132	1.0760	0.7639	.89	3.21
Exponential	0.0390	0.4031	1.2332	0.0167	.85	3.71
Log-Linear**	0.7535	0.5014	0.7386	0.4821	.70	.31

NOTES: N = 179; all coefficients are significant at the .001 level; equation 4 F-statistic = 134.79, level of significance = > .99; ** indicates equation incorporated in MANPOWER.

Table A.12

ALTERNATIVE FORMULATIONS OF THE RELATIONSHIP BETWEEN MANNING AND SELECTED INDEPENDENT VARIABLES IN NONINTEGRATED AVIONICS MAINTENANCE

Equation Form	Constant	Coefficients of Independent Variables			R^2	SEE
		MMH/S	Sortie Rate	UE		
Linear	-19.780	5.7767	15.864	0.2284	.69	7.2
Power	0.3881	0.9053	1.2336	0.8743	.97	2.3
Exponential	-0.4983	0.2587	1.7028	0.0198	.77	6.3
Log-Linear**	0.49871	0.5940	0.7432	0.5192	.81	.30

NOTES: N = 190; all coefficients are significant at .01 level; equation 4 F-statistic = 265.73, level of significance = > .99; ** indicates equation incorporated in MANPOWER.

Table A.13

ALTERNATIVE FORMULATIONS OF THE RELATIONSHIP BETWEEN MANNING AND SELECTED INDEPENDENT VARIABLES IN INTEGRATED AVIONICS MAINTENANCE

Equation Form	Constant	Coefficients of Independent Variables: MMH/S	Sortie Rate	UE	R^2	SEE
Linear	52.86	4.34	-78.21 (.08)	.825	.92	15.3
Linear	-20.551	5.2978	---	0.8284	.89	17.2
Power	0.7921	0.7197	---	0.7960	.99	5.6
Exponential	2.0779	0.0791	---	0.0243	.88	18.7
Log-Linear**	0.9000	0.6229	---	0.5200	.88	.45

NOTES: N = 14; all coefficients are significant at the .01 level except where indicated in parentheses; equation 5 F-statistic = 39.48, level of significance = > .99; ** indicates equation incorporated in MANPOWER.

to program the log-linear forms of the equations in MANPOWER rather than the linear because the former are more sensitive to changes in the sortie rate. In addition, the log-linear equations fit the data slightly better in all cases. In choosing between the power and log-linear forms of the equations, analysis of the plot of Y residuals versus fitted values (or residuals of log Y versus fitted log Y for the logarithmic case) revealed better random normal distributions of the Y residuals around the zero line for the log-log equations than for the power equations.

It should be noted that in integrated avionics the sortie rate has a negative coefficient. This occurs because even though the F-111D has a lower sortie rate than the F-16, it has a higher personnel requirement when the workload and UE are held constant. This anomaly is caused by the severe problems that have occurred in the maintenance of the F-111D Mark II avionics. We do not believe it is

reasonable to include sortie rate as a negative factor in the prediction equation for integrated avionics; therefore, the log-linear equation, which excludes sortie rate, is used to predict the personnel requirements in integrated avionics shops.

APPLICATION OF THE EQUATIONS

Two facets of the application of the LCOM equations must be emphasized:

First, the equations are evaluated separately for each deployment unit at a peacetime base. Thus, for example, if three squadrons are to be deployed two-ways, each of the equations for Flight Line, Jet Engine Shop, Aerospace Systems, and Avionics is evaluated first for two squadrons and then again for one squadron. The total base personnel requirement in each work center group is the sum of the requirements for the two deployment units.

Second, the equations for Aerospace Systems and Avionics are for individual shops; thus, the equations should be applied once for each shop in the work center group. In the Aerospace Systems and Structural Repair group, there are seven shops. In Avionics, the number of shops is a user input. In calculating the personnel requirement for these groups of work centers, it is assumed that the workload is divided equally among the shops. Thus, the equation is evaluated once and the resulting number of positions is multiplied by the appropriate number of shops to yield the total personnel requirement for the group of work centers.

Appendix B

STANDARD MANNED WORK CENTERS

We have designated as "standard manned" all aircraft maintenance work centers where requirements are determined currently by techniques other than LCOM simulation. The calculation procedures incorporated in the model for each of these work centers will be documented in this appendix, which is organized into the following sections:

- Chief of Maintenance
- Corrosion Control
- Survival Equipment
- Nondestructive Inspection
- Aerospace Ground Equipment
- ECM Pods
- Munitions Maintenance
- Shop Overhead and Supervision
- Officers and Enlisted Personnel

Statistical standards are based on a variety of conventional work analysis techniques including time study, work sampling, standard data, operational audit, and record analysis. Linear regression analysis is used to find a program variable (such as flying hours, sorties, or units of equipment) that is strongly correlated with the observed workload in the work center under study. This variable is then used to predict the workload in a new environment. The predicted workload (in manhours) is translated to a manning requirement by dividing by the number of hours an individual worker is available for productive labor (144 hours a month during peace and 242 hours a month during war).

The adaptation of the statistical standards for MANPOWER was relatively straightforward. The manning for each work center (with only two minor exceptions in Munitions Maintenance) is calculated separately.

In many cases, the program variable was one that could be stipulated early in the acquisition process; these standards have been adopted directly in the computer model (most Chief of Maintenance standards are examples of this type of work center). In a few cases, however, the standard workload factors could not be easily estimated prior to the DSARC II decision. In such an event, actual authorizations for the work center at representative bases were examined to find a simple predicting relationship (see, for example, Nondestructive Inspection). Similarly, in those cases where a statistical standard does not exist, actual authorizations were analyzed to determine a simple estimating technique (see Corrosion Control, for example).

Another potential problem was the use of different standards for different aircraft types. Fortunately, we found that most standards were applied uniformly across aircraft types. Three exceptions were treated as follows. First, small differences (of one or two positions) across aircraft types were ignored; the modal value for the work center was adopted in MANPOWER (for example, Quality Control). Second, in several work centers reconnaissance aircraft require fewer personnel because of mission differences and their lower sortie rate. The lower requirement for reconnaissance aircraft was explicitly incorporated in the model (see, for example, Munitions Maintenance). Third, the F-111 has had numerous maintenance problems, necessitating more maintenance personnel. Where this additional requirement stems from the quantity or kind of avionics on-board, we have attempted to incorporate it in the model (Integrated Avionics are explicitly addressed in AGE and Overhead/Supervision requirements). However, extra indirect personnel requirements resulting from extraordinary problems are not incorporated in the model. The model user should bear in mind that additional indirect labor and support are usually required when unique problems occur in the maintenance activity.

Finally, peacetime requirements are calculated using personnel availability of 144 hours per month. Wartime requirements use an

availability of 242 hours per month. To insure that sufficient personnel are available in the wartime environment, the contingency minimum personnel requirement serves as the absolute minimum.

The following variable abbreviations are used frequently in this appendix (others, used only once, are defined at the place of occurrence):

S_p = Number of sorties per month during peace
S_w = Number of sorties per month during war
FH_p = Flying hours per month during peace
FH_w = Flying hours per month during war
UE = Number of aircraft at a peacetime base or wartime deployment
M2XXX = Manning in work center 2XXX
Min = Minimum manning in a work center
Max = Maximum manning in a work center
R = Reconnaissance mission
A = Attack mission
F = Fighter mission

CHIEF OF MAINTENANCE

The responsibility of the Chief of Maintenance is to plan, administer, and evaluate wing aircraft maintenance. The following figure shows the organization of these activities:

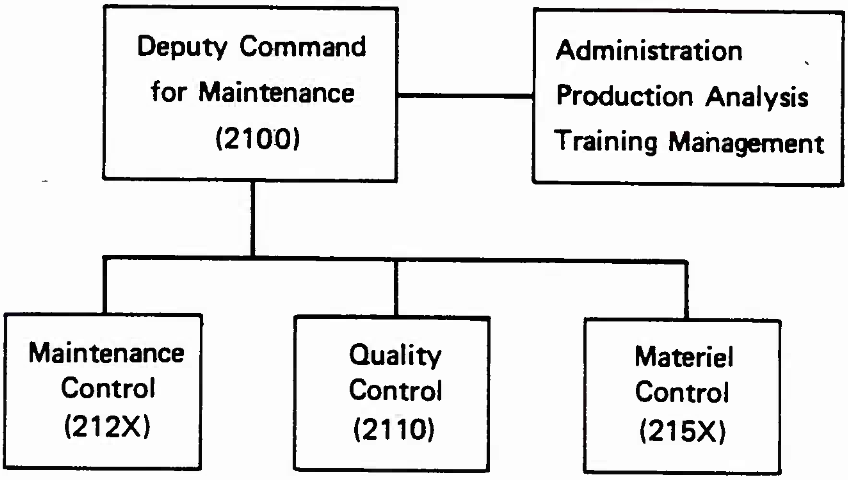

Figure — Organization of Chief of Maintenance

Maintenance Control schedules and assigns tasks while tracking the status of work in progress. Quality Control evaluates the methods and performance of individuals and work centers. And Material Control monitors repairable assets and the inventory of spare parts. Above these divisions stands the Deputy Commander for Maintenance (the DCM) and his staff for Administration, Production Analysis, and Training Management. In a typical wing (72 aircraft, two-way deployment), Chief of Maintenance will employ roughly 150 people; this amounts to 10-15 percent of the total maintenance personnel requirement.

The manning of Chief of Maintenance work centers is determined by the application of TAC statistical standards and classified contingency requirements. The contingency requirements are the basis for manning when peacetime manning calculations do not generate sufficient personnel to meet wartime requirements.

Table B.1 summarizes the statistical standards applicable as of the first quarter of FY 1977. The standards apply to the older aircraft types in the Air Force inventory (F-4, RF-4, A-7, and F-111) and are expected to apply to incoming systems (A-10, F-15, and F-16). There is *little variation across aircraft types* in the number of personnel allocated by standard equation or contingency requirement. Differences exist between aircraft in the contingency requirements for Quality Control (2110) and Production Control (2153); however, these differences are minor compared to the magnitude of the total allocation for Chief of Maintenance. The lower requirement in Production Control for the RF-4 is incorporated in the model as a "minimum" to apply in the case of new reconnaissance aircraft.

The footnotes to Table B.1 indicate that additives are common in Chief of Maintenance. These apply primarily to the F-111, which has had many unique maintenance problems (particularly in the areas of Avionics and Quality Control). We have not attempted to incorporate this exceptional case in the model because of the uncertainty associated with such requirements and their relatively minor magnitude. The analyst should recognize that extraordinary maintenance problems usually will generate greater supervisorial and overhead requirements than are normally required.

Table B.1

CHIEF OF MAINTENANCE PERSONNEL AUTHORIZATION STANDARDS

Functional Area		Workload Factor	Standard Equation[a]	Range of Personnel[b] MAF:Range
2100	Chief of Maintenance (includes Administration, Production Analysis, and Training Management)	Programmed Flying Hours/Month (includes mission and base support aircraft)	Y = 2125.6 + .5032(FH)[c]	144:18-26 180:14-21 242:11-16
2110	Quality Control	Programmed Sorties/Month (all authorized UE aircraft)	Y = 3477.2 + .7469(S)[d]	144:26-33 180:21-26 242:16-20
2120	Maintenance Control	Constant Manned	Y = 475.397	144: } 4 180: } 4 242: } 4
212X	Job Control	Programmed Flying Hours/Month (includes mission and base support aircraft)	Y = 1082.7 + 1.143(FH)[e]	144:16-33 180:13-27 242:9-21
212X	Plans and Scheduling	Programmed Sorties/Month (all authorized UE aircraft)	Y = 532.8 + 1.0813(S)	144:6-17 180:5-15 242:4-12
212X	Documentation	Authorized UE Aircraft (including mission and base support aircraft)	Y = 264.2 + 6.393(UE)	144:2-8 180:2-7 242:2-5
2150	Materiel Control	Programmed Sorties/Month (all authorized UE aircraft)	$Y = 19.18(S)^{.4269}$	144:1-4 180:1-4 242:1-3
215X	Maintenance Supply Liaison	Programmed Sorties/Month (all authorized UE aircraft)	Y = 505.8 + 1.013(S)[f]	144:6-17 180:5-15 242:3-11
215X	Production Control	Programmed Sorties/Month (all authorized UE aircraft)	Y = 713.7 + .9658(S)[g]	144:7-16 180:6-15 242:5-12

NOTE: Table footnotes appear on p. 31.

NOTES TO TABLE B.1

SOURCES: TACR 26-3, 9 January 1976; initial application: FY 1/77. These standards are applicable to all Tactical Air Command Wings except the 4500th ABWg, Langley Air Force Base, and the Chief of Maintenance function at Hurlburt (fld #9). These standards are designed to provide adequate personnel authorizations for a peacetime environment; contingency manning standards apply for those work centers where additional personnel are required for a wartime environment.

[a]The standard equation yields the total manhours required in a functional area. This requirement divided by the number of hours available per worker yields the personnel authorization. Both peacetime and wartime workload factors can be used in these equations; therefore, subscripted variables are not used in the standard equation.

[b]The range of personnel is the maximum and the minimum number of personnel authorized at the extrapolation limits of the equation for each level of personnel availability. The manpower availability factor (MAF) is the number of hours an individual is expected to be available for work each month. The wartime factor is 242; the usual peacetime factor is 144.

[c]Additives: Mountain Home receives one in the Administration work center and three in the Production Analysis work center, irrespective of the MAF used.

[d]Additives: Nellis receives five additional spaces, irrespective of the MAF used.

[e]Additives: The 33rd at Eglin Air Force Base is a two squadron wing. The workload factor (FH) for the Job Control work center does not provide sufficient manning to cover the minimum required manning. Consequently, this work center at Eglin is position manned with 20 spaces authorized. Problems with the Mark II avionics on the F-111D at Cannon require that five extra personnel spaces be authorized.

[f]Additives: Mountain Home receives five additional spaces, irrespective of MAF used. Nellis (with 90 F-111 aircraft) receives a total of 16 authorized spaces. Cannon receives three additional personnel spaces.

[g]Additives: Mountain Home receives 11 additional spaces, irrespective of MAF used. Because of problems with the Mark II avionics, Cannon receives 19 additional personnel spaces.

The values of the workload factors in the standard equations can be stipulated early in the acquisition process, since these are programmed flying hours, sorties, units of equipment, and squadrons. In Tables B.2 and B.3, the calculation procedures for various combinations of peacetime basing and wartime deployment are displayed for two Chief of Maintenance work centers: Plans and Scheduling and Maintenance Supply Liaison. MANPOWER determines the appropriate manning (which is the greater of peacetime and wartime requirements) based on the variable values supplied by the user.

CORROSION CONTROL (2314)

Corrosion Control is one of the work centers that does not have a statistical standard. Its personnel needs are evaluated annually by TAC analysts. The requirement for Corrosion Control depends on numerous factors, but particularly important are the number of aircraft, current policies regarding the frequency of application of the corrosion treatment, and the climatic conditions at the base where the aircraft are located. Since not all these factors are known early in the DSARC process, regression analysis was used on current authorizations for Corrosion Control at existing bases to determine a usable prediction relationship. These data are summarized in Table B.4. (This exhibit also displays data for Survival Equipment and Nondestructive Inspection work centers, which also have manning standards based on factors not available early in the DSARC process.)

The Corrosion Control authorizations in 36 cases for A-7, F-15, RF-4, F-4, F-111, F-16, and F-105 aircraft were analyzed. A linear equation, with number of aircraft (UE) as the independent variable, provides a satisfactory personnel estimating equation. Other equations (e.g., power, exponential, logarithmic, and semilogarithmic) did not generate more accurate predictions. The percentage error in the linear relationship is greater than ideal; however, the small number of personnel in this work center and the complexity of the conditions that determine the manning requirement suggest we can be satisfied with this simple relationship:

Table B.2

CHIEF OF MAINTENANCE PERSONNEL REQUIREMENTS: WORK CENTER 2122, PLANS AND SCHEDULING

Peacetime Basing (No. of Squadrons at Base)	Peacetime Requirement	Wartime Requirement When Deployment Is:			
		One-Way	Two-Way	Three-Way	Four-Way
1	$\frac{532.8 + 1.0813(S_p)}{144}$	$\frac{532.8 + 1.0813(S_w)}{242}$			
2	Same as above	Same as above	$\frac{532.8 + 1.0813(S_w)}{242}$		
3	Same as above	Same as above	Same as above	$\frac{532.8 + 1.0813(S_w)}{242}$	
4	Same as above	Same as above	Same as above 2-2 3-1	Same as above	$\frac{532.8 + 1.0813(S_w)}{242}$

Table B.3

CHIEF OF MAINTENANCE PERSONNEL REQUIREMENTS: WORK CENTER 2151, MAINTENANCE SUPPLY LIAISON

Peacetime Basing (No. of Squadrons at Base)	Peacetime Requirement	Wartime Requirement When Deployment Is:			
		One-Way	Two-Way	Three-Way	Four-Way
1	$\frac{505.8 + 1.013(S_p)}{144}$	$\frac{505.8 + 1.013(S_w)}{242}$			
2	Same as above	Same as above	$\frac{505.8 + 1.013(S_w)}{242}$		
3	Same as above	Same as above	Same as above	$\frac{505.8 + 1.013(S_w)}{242}$	
4	Same as above	Same as above	Same as above 2-2 3-1	Same as above	$\frac{505.8 + 1.013(S_w)}{242}$

Table B.4

MAINTENANCE PERSONNEL AUTHORIZATIONS FOR SELECTED WORK CENTERS

Aircraft Type	Authorized UE	Corrosion Control	Survival Equipment	Nondestructive Inspection
F-15	72	9	7[a]	14
F-15	24	2	5	3
F-15	66	9	8	14
F-15	72	9	7[a]	14
F-15	72	8	10	8
F-111	60	10	9	11
F-111	72	25[a]	4[a]	9
F-111	72	10	12	16
F-111	72	11	12	11
RF-4	54	9	9	11
RF-4	54	10	9	12
RF-4	54	9	11	3[a]
RF-4	36	7	8	3
F-105	36	8	7	6
A-7	54	6	9	6
A-7	72	8	13	9
A-7	66	8	10	8
F-4	96	20	14	14
F-4	72	14	12	9
F-4	18	2	8	3
F-4	90	11	12	5[a]
F-4	48	11	13	5
F-4	72	11	13	5[a]
F-4	24	6	4	5
F-4	48	7	8	1[a]
F-4	12	3	6	3
F-4	18	4	4	3
F-4	24	5	5	4
F-4	72	14	12	9
F-4	24	5	5	3
F-4	72	8	9	5[a]
F-4	72	14	12	10
F-4	18	5	5	7
F-4	72	13	15	5[a]
F-16[b]	24	2	4	4
F-16	48	3	8	6
F-16	72	8	10	8

[a] These points are outliers in the scatter diagrams of the data. They were omitted from the regression analyses. Many factors (which are beyond the scope of this inquiry), such as collocation of squadrons, the availability of personnel, and the transfer of personnel and aircraft from base to base, cause these apparent anomalies.

[b] The data in these F-16 cases come from an unpublished F-16 SPO study of the maintenance personnel requirements (Wright-Patterson Air Force Base, October 1976).

$$M2314 = .92 + .14 (UE)$$

Statistics

$R^2 = .65$

Standard error of estimate = 2.34

$F(1, 34) = 63.86$ LS > 99%

b T-ratio = 7.99 LS > 99%

Mean absolute relative deviation = 30%

This equation yields the following manning for deployment units (Table B.5):

Table B.5

MANNING FOR DEPLOYMENT UNITS IN THE CORROSION CONTROL WORK CENTER

UE Deployed	90% Confidence Interval: Lower Bound	M2314	90% Confidence Interval: Upper Bound
18	0	4	8
24	1	4	8
36	2	6	10
48	4	8	11
54	5	8	12
72	7	11	15
90	9	13	17
96	10	14	18

SURVIVAL EQUIPMENT (2315)

The Survival Equipment work center maintains parachute assemblies, life rafts, life preservers, gas masks, leather equipment, and flying clothing.

The manning of this work center requires evaluation of a set of fairly complex equations and alternatives. Because TAC aircraft have diverse missions and crews of one or two, the manning in Survival Equipment varies by aircraft type. Also, the personnel requirement varies between peacetime and wartime scenarios and between training and combat coded aircraft. The peacetime and training requirements are a function of number of aircraft and/or sorties, whereas the

wartime requirement is a function of the number of deployment locations and number of aircraft.

The peacetime standards are provided for reference:*

(1) F/RF-4 and F-105

$$y = \frac{z}{.0576 + .0002695z}$$

where

$z = x_1 + .7724x_2 + .0728x_3 + .1026x_4$

x_1 = UE F/RF-4

x_2 = UE F-105

x_3 = programmed F/RF-4 sorties

x_4 = programmed F-105 sorties

y = manhours

Range of personnel @ 144 manhours/month = 2 - 15

Range of personnel @ 242 manhours/month = 2 -9

(2) F-111

$$y = 10.54 + 6.877x$$

where

x = UE F-111

y = manhours

Range of personnel @ 144 manhours/month = 1 - 5

Range of personnel @ 242 manhours/month = 1 - 3

(3) A-7D

$$y = 9.516x$$

---

*SOURCE: Air Force Form 110, *Survival Equipment*, Management Engineering Division, Directorate of Manpower and Organization (XPMM), Headquarters, Tactical Air Command, Langley Air Force Base, September 1976.

where

x = UE A-7D

y = manhours

Range of personnel @ 144 manhours/month = 1 - 6

Range of personnel @ 242 manhours/month = 1 - 3

Notwithstanding the complex calculation procedures, we must observe that the total manning for the maintenance of survival equipment does not exceed 15 people in a wing of 72 aircraft (see Table B.4). In addition, analysis of authorizations for this work center for the F-15, F-105, A-7, F-16, and F-4 in 34 cases reveals a fairly strong direct relationship between UE and manning:

M2315 = 3.02 + .12 (UE)

Statistics

R^2 = .74

Standard error of estimate = 1.63

F(1, 32) = 90.64 LS > 99%

b T-ratio = 9.52 LS > 99%

Mean absolute relative deviation = 15%

This equation is satisfactory for our purposes. It yields the mannings for deployment units as shown in Table B.6.

NONDESTRUCTIVE INSPECTION (2317)

The Nondestructive Inspection (NDI) work center is manned by a TAC statistical standard. The workload factor in this standard is "total number of weighted equivalent inspections." Inspection types are weighted as follows:*

---

*SOURCE; Air Force Form 1110, *Nondestructive Inspection*, Management Engineering Division, Directorate of Manpower and Organization (XPMM), Headquarters, Tactical Air Command, Langley Air Force Base, September 1976.

Inspection Type	Weight
Liquid Penetrant	.26
Magneto Particle	.23
Electro Magnetic	.29
Ultrasonic	.35
X-Radiation	1.00
Optical	.19

This factor is obviously not satisfactory for a model that is to be exercised very early in the acquisition process. Therefore, analysis was undertaken using the data in Table B.4 to find a more accessible workload factor.

Table B.6

MANNING FOR DEPLOYMENT UNITS IN THE SURVIVAL EQUIPMENT WORK CENTER

	90% Confidence Interval		
UE Deployed	Lower Bound	M2315	Upper Bound
18	3	5	8
24	3	6	8
36	5	7	10
48	6	9	11
54	7	9	12
72	9	11	14
90	11	13	16
96	11	14	17

The wartime minimum manning in the Nondestructive Inspection work center is seven, and the maximum indicated in the standard is 16. Regression analysis revealed a substantial relationship between authorizations for Nondestructive Inspection and UE at the base. There was no apparent systematic variation by aircraft type. The linear equation was:

$$Y = .89 + .14\ (UE)$$

where Y = number of personnel authorized

$R^2 = .66$

Standard error of estimate = 2.35

$F(1, 29) = 56.40$ LS > 99%

b T-ratio = 7.51 LS > 99%

Mean absolute relative deviation = 25.0%

Since minimum manning for Nondestructive Inspection, according to the standard, is seven, we will shift this equation to guarantee this minimum manning for 18 UE deployments.

The equation incorporated in the model is:

$$M2317 = 4.48 + .14\ (UE)$$

This equation yields the manning requirements as shown in Table B.7.

AEROSPACE GROUND EQUIPMENT

There are three work centers responsible for the handling, inspection, and repair of powered AGE: *Repair and Inspection* (work center 2341) maintains the equipment and conducts periodic, phase, and special inspections; *Servicing, Pickup, and Delivery* (work center 2342) transports the AGE between shops, usage sites, and storage areas and performs routine servicing; and *Aerospace Ground Equipment-Management* (work center 2340) provides administration and general support for the two operating divisions.

Aerospace Ground Equipment provides power, pressure, heating, and cooling during maintenance of an aircraft. In addition, certain types of aircraft need AGE to start the jet engines. Powered AGE includes air compressors, generators, blowers, hydraulic test stands, air conditioners, bomb lifts, floodlight sets, heaters, and jacking units.

Table B.7

MANNING FOR DEPLOYMENT UNITS IN THE NONDESTRUCTIVE INSPECTION WORK CENTER

	90% Confidence Interval		
UE Deployed	Lower Bound	M2317	Upper Bound
18	3	7	11
24	4	8	12
36	6	9	13
48	7	11	15
54	8	12	16
72	10	14	18
90	12	17	21
96	12	17	23

Two standards for AGE maintenance have been developed by TAC analysts: a peacetime standard in which personnel requirements are a function of the number of pieces of powered AGE in the squadron or wing; and a wartime standard in which the requirement is a function of the number of sorties flown. The two standards are documented in Tables B.8 and B.9.

TAC analysts indicate that the wartime standard serves as the basis for manning combat coded squadrons. Based on the expected wartime sortie rate, the contingency personnel requirements typically are greater than those for the peacetime environment. Consequently, in MANPOWER, AGE manning is calculated by multiplying the appropriate wartime MMH/S factor (shown in Table B.8) by the total monthly wartime sorties and dividing this product by the wartime availability factor of 242 hours a month.*

---

*Since it is unlikely that the user of MANPOWER will be able to provide an educated estimate of the number of pieces of AGE a new aircraft will require, the peacetime personnel requirement for this work center is calculated using the peacetime sortie rate and the same MMH/S factor.

Table B.8

WARTIME STANDARDS FOR AEROSPACE GROUND EQUIPMENT
WORK CENTERS INCORPORATED IN MANPOWER

2340--Management

UE	Personnel Requirement	UE	Personnel Requirement
16	3	56	6
18	4	64	6
24	4	72	6
32	5	84	7
36	5	90	7
48	5	96	8
54	6		

2341--Repair and Inspection

Aircraft Mission/Design/Series	MMH/S
A-7, A-10, F-4 (Traditional Avionics)	3.49
F-15, F-111 (Advanced Avionics)	6.20

2342--Service, Pickup, and Delivery

Aircraft Mission/Design/Series	MMH/S
A-7, A-10, F-4 (Traditional Avionics)	4.44
F-15, F-111 (Advanced Avionics)	7.90

RF-4C Contingency Minimum Manning

UE	Personnel Requirements 2341	Personnel Requirements 2342
3	4	4
6	4	4
9	6	6
18	8	8

SOURCES: Derived from Air Force Form 1110, *Aerospace Ground Equipment* (2340, 2341, and 2342), obtained from the Office of the Directorate of Manpower and Organization (XPM), Headquarters, Tactical Air Command, Langley Air Force Base, April 1976; and *Contingency Manpower Requirements for Aerospace Ground Equipment Work Centers*, August 1975, obtained from the same office.

Table B.9

PEACETIME STANDARDS FOR AEROSPACE GROUND EQUIPMENT WORK CENTERS
(Availability = 144)

2340 Manhours = 44.72 + 7.835 (personnel in 2341 + 2342)

2341 Manhours = 144.20 + 14.740 (pieces of AGE authorized)

2342 Manhours = 39.44 + 19.670 (pieces of AGE authorized)

SOURCE: Air Force Form 1110, *Aerospace Ground Equipment* (2340, 2341, and 2342), Office of the Directorate of Manpower and Organization (XPM), Headquarters, Tactical Air Command, Langley Air Force Base, April 1976.

ECM PODS

Personnel requirements for ECM Pod Maintenance (2413) are determined by engineering standards. The TAC standard for the ECM work center is: Personnel = .42 UE.* Total authorizations for TAC are determined by this standard. However, the distribution of these personnel to bases may not agree with the above equation. Because of peculiar missions and deployments, certain squadrons or wings may be assigned more or fewer personnel than the standard would indicate. This is evident from the data in Table B.10, which shows the number of aircraft and 2413 personnel for 13 TAC bases. Despite these anomalies, we use .42 (UE) in MANPOWER to allocate manning for ECM Pod Maintenance.

MUNITIONS MAINTENANCE, 25XX

The Munitions Maintenance work centers are responsible for loading, inspecting, and repairing the missiles and munitions assigned to the squadron or wing and for inspecting and maintaining the aircraft's guns and weapons release systems. In addition to the maintenance

---

*SOURCE: Letter to C. D. Roach from Colonel Jerald D. Cannon, Chief, Management Engineering Division, Directorate of Manpower and Organization (XPMM) dated July 23, 1976.

Table B.10

AUTHORIZATIONS FOR ECM POD MAINTENANCE (2413)
AT REPRESENTATIVE TAC BASES

UE	No. of Personnel Authorized for 2413	No. Based on Standard
54	29	22
72	29	30
72	25	30
54	23	22
66	33	27
96	38	40
90	28	37
72	25	30
72	29	30
48	19	20
40	22	16
66	35	27
36	23	15
838	358	352

ECM Standard: .42(838) = 352

oriented work centers, there are supervisory and overhead functional areas responsible for the administration, training, and control of the Munitions Maintenance personnel.

Personnel authorizations for the Munitions Maintenance work centers of the Tactical Air Command typically have been based on statistical standards. Steps are being taken, however, to incorporate Munitions Maintenance in the LCOM simulation model. Since, as of this date, only a few of the Munitions Maintenance work centers have been simulated for two aircraft, the traditional standards are incorporated in MANPOWER.

The standards used to man the Munitions Maintenance work centers* are shown in Table B.11. The standards that indicate constant manning or use an equation to estimate requirements in *hours* are peacetime

---

*Some recent changes have been made in the numerical designations of the work centers. Missile Maintenance, 2521, is now 2526; Munitions Maintenance, 2521, is now 2523; Equipment Maintenance, 2523, is now 2550. The former designations will be used in this report.

Table B.11

MUNITIONS MAINTENANCE WORK CENTERS

Work Center	Title	Standard
2500	Commander	Constant manning = 2
2500	Maintenance Supervision	Constant manning = 3
2500	Training	Constant manning = 2
2500	Mobility	Hours = $133.1 - .11(P_1) + .0008048(P_1)^2$
2500	FK (Munitions Supply Account.)	Hours = $242.2 + .5123(WO)$
2500	Technical Administration	Constant manning = 2
2500	Standardization	Constant manning = 6
2500	Munitions Control	Hours = $170.6 + .8299(WO)$
2500	Administration	Hours = $2.01(P_2)^{.9889}$
2510	Munitions Services	Constant manning = 2
2511	Weapons Loading	Personnel = $2(UE) + 4(SQ)$
2512	Weapons Release	F-111: Wartime Contingency Standard All other: Wartime Contingency Standard
2513	Gun Services	Wartime Contingency Standard
2520	Maintenance and Storage	Hours = $\dfrac{P_3}{.06646 + .001186(P_3)}$
2521	Missile Maintenance	Wartime Contingency Standard
2521	Munitions Maintenance	Wartime Contingency Standard
2522	Storage and Handling	Wartime Contingency Standard
2523	Equipment (Trailer) Maintenance	Hours = $144.2 + 7.595(T_1) + 22.72(T_2)$
2525	Inspection	Hours = $\dfrac{(L)}{.3120 + .00006417(L)}$

NOTE: For appropriate equations, personnel requirements equals hours divided by 144.

Predicting Variables:

P_1 = number of personnel on mobility status
WO = number of work orders processed
P_2 = number of military personnel authorized in 25XX
SQ = number of squadrons
P_3 = total authorizations for 252X (excluding 2520)
T_1 = number of 2-1/2 ton trailers
T_2 = number of 7-1/2 ton trailers
L = number of line items stocked by 2522 work center

standards, which are also applicable for contingency operations. The hours are translated to personnel requirements by dividing the total hour requirements by the peacetime availability of 144. The resulting peacetime manning levels are sufficient to cover wartime requirements when the availability is increased to 242 hours. The remaining standards, which directly predict personnel requirements, are wartime standards which (except for weapons loading) were developed by USAFE using assembly line simulation techniques and queueing theory. Although the resulting manning levels reflect wartime requirements, these contingency standards also are used to man the appropriate work centers in peacetime. In short, each work center in the Munitions Maintenance area has only one equation to predict personnel requirements, which may be based in either a peacetime or contingency scenario. As a result, questions concerning peacetime versus wartime manning do not arise. Also, the number of separate locations to which a wing will deploy in wartime is not considered in manning Munitions Maintenance work centers.

To give an indication of the number of personnel in the Munitions Maintenance shops, Table B.12 shows Munitions Maintenance authorizations for various tactical aircraft at a number of TAC and USAFE bases. These values do not represent a single point in time; the F-15 and A-10 data are estimated authorizations for a 1980 time frame; for the other aircraft, they are actual authorizations for 1975 and 1976. For most work centers, different numbers of personnel will be authorized for the same number of a given type of aircraft at different bases. Because of base peculiarities or because of a particular mission or function of a wing or squadron, manning in certain work centers may be augmented or decremented. Also, there may be differences between the required manning, as determined by TAC through the standards, and the authorized manning as determined by Headquarters, USAF. Therefore, there may be some deviation from the manning levels suggested by the standards.

The majority of the standards in Table B.11 could readily be used early in the acquisition process. A few standards, however,

Table B.12

MUNITIONS MAINTENANCE AUTHORIZATIONS

Aircraft	UE	2500	2510	2511	2512	2513	2520	2521	2522	2523	2525	Total
F-4	18	15	1	36	9	7	1	19	8	1	2	99
	18	30	2	41	9	8	2	45	36	3	4	180
	24	11	3	54	15	12	-	-	-	-	-	95
	24	40	2	52	19	17	5	20	26	6	6	193
	42	30	2	93	21	17	2	44	37	3	4	253
	48	31	2	104	25	24	4	37	46	4	-	277
	48	31	1	101	21	19	2	53	39	4	4	275
	66	33	2	143	31	26	2	57	39	6	6	345
	72	34	2	153	34	27	2	53	54	5	8	372
	72	36	2	156	39	36	5	54	68	7	6	409
	72	33	2	151	34	25	2	42	45	5	8	347
	72	34	2	156	39	36	4	53	66	9	10	409
	72	36	2	156	38	36	4	54	67	6	7	406
	96	37	2	208	50	48	5	68	81	7	11	517
F-15	72	33	2	151	31	26	2	57	39	6	6	353
	72	35	2	156	38	36	5	51	61	7	12	403
	72	39	2	156	38	36	4	54	67	4	3	403
	72	34	2	156	38	36	4	54	67	7	6	404
F-111	60	28	2	157	72	36	-	28	35	-	-	358
	48	30	2	104	43	27	-	18	28	-	-	252
	72	38	2	156	63	42	4	37	45	4	6	397
	72	34	2	149	69	42	2	36	37	5	6	382
	84	39	2	180	75	49	4	34	52	5	6	446
A-7	72	38	2	156	36	33	4	44	57	5	2	377
	72	36	2	156	35	32	4	44	55	7	4	375
	72	36	2	156	35	32	4	44	55	4	6	374
A-10	72	32	2	157	35	32	4	44	53	3	4	368
RF-4C	18	3	1	34	6	-	-	-	-	-	-	44
	54	10	2	-	44	-	30	-	-	-	3	89
	36	10	2	-	36	-	13	-	-	-	4	65
	36	9	-	22	4	-	5	-	-	1	2	79

require predicting variables, such as number of work orders or line items stocked, which may not be known in the time frame of interest. It is desirable for these work centers to find alternative techniques involving surrogate variables that are identifiable. To find these alternative equations, the actual Munitions Maintenance authorizations from Table B.12 were examined. The development of these alternative equations and the personnel requirements for reconnaissance aircraft are described below.

FK (Munitions Supply Accountability) and Munitions Control, 2500

The majority of the 2500 work centers are responsible for the supervision, training, and administration of the Munitions Maintenance personnel. The personnel requirements for these shops are constant or a function of the number of personnel in the remaining 25XX work centers. The two remaining 2500 work centers, FK (Munitions Supply Accountability) and Munitions Control, are responsible for the processing and control of the missiles and munitions assigned to the squadrons or wing. The standards for these shops use number of work orders processed to estimate the required personnel.

Since the number of work orders processed is a variable that will not be known early in the acquisition process, an alternative personnel estimating relationship was developed for FK and Munitions Control. Because the functional responsibilities of these two work centers are munitions related, it can be assumed that the more munitions assigned to a unit, the more personnel would be required in the FK and Munitions Control shops. A similar relationship between numbers of personnel and numbers of munitions also probably exists for 2521, Missile and Munitions Maintenance, and 2522, Storage and Handling. Then, if these assumptions are correct, the number of personnel in FK and Munitions Control should be related to the number of personnel in the 2521 and 2522 work centers.

Another variable that must be considered is whether or not the aircraft has an air superiority mission. Air-to-air missiles require more personnel in the 2521 and 2522 shops than air-to-ground missiles

or conventional bombs. To estimate the number of personnel in FK and Munitions Control, adjustments must be made for those air superiority aircraft that have "extra" personnel in the 2521 and 2522 shops because they have air-to-air missiles.

The numbers of personnel authorized for the FK and Munitions Control work centers were estimated by subtracting from the total 2500 authorizations in Table B.12 the number of personnel implied by the standards for the remaining 2500 shops. A linear relationship was then calculated between the number of personnel in FK and Munitions Control and the number of personnel in the 2521 and 2522 work centers; a dummy variable for the mission of the aircraft was included (0 if there is an air superiority mission, 1 otherwise).* The resulting equation and the estimated authorizations are shown in Table B.13. This equation will be used in the model to estimate total personnel requirements for the FK and Munitions Control work centers.

Equipment (Trailer) Maintenance, 2523 and Inspection, 2525

Equipment Maintenance and Inspection are the other two work centers where the standards require predicting variables (number of trailers and number of line items, respectively), which will not be known early in the acquisition process. Alternative estimating equations are therefore required for these two work centers.

As was the case with the FK and Munitions Control shops, the number of personnel in Equipment Maintenance and Inspection can be assumed to be a function of the number of munitions assigned to the squadron or wing and therefore also should be positively correlated with the number of personnel in the 2521 and 2522 work centers. Because a relationship did not appear to exist when examining 2523 and 2525 individually, the combined manning in these two shops was compared

---

*In effect, this adjusts downward the FK and Munitions Control manning in air superiority wings to offset the upward bias created by the extra personnel required per air-to-air missile.

Table B.13

ALTERNATIVE STANDARD FOR FK AND MUNITIONS CONTROL WORK CENTERS

Total 2500	Constant Mobility and Administration	FK and Mun. Control	2521 + 2522 Personnel	Estimated FK and Mun. Control[a]	Percent Deviation[b]
30	19	11	81	11	0
30	19	11	81	11	0
31	20	11	83	11	0
31	20	11	92	12	-9.1
34	21	13	107	13	0
36	21	15	122	14	6.7
33	21	12	87	12	0
34	21	13	119	13	0
36	21	15	121	14	6.7
33	21	12	96	12	0
37	23	14	149	15	-7.1
33	21	12	96	12	0
35	21	14	112	15	-7.1
39	21	18	121	16	11.1
34	21	13	121	16	-23.1
38	21	17	82	14	17.6
34	21	13	73	13	0
39	22	17	86	14	17.6
38	21	17	101	15	11.8
36	21	15	99	15	0
36	21	15	99	15	0
32	21	11	97	15	-36.4
28	19	9	63	12	-33.3
					Av. = 8.2

$$\left(\begin{array}{c}\text{Personnel in FK}\\ \text{and Munitions Control}\end{array}\right) = 6.25 + .06 \left(\begin{array}{c}\text{Personnel in 2521 and}\\ \text{2522 Work Centers}\end{array}\right) + 2.38 \left(\begin{array}{l}\text{0, if air}\\ \text{superiority,}\\ \text{1, otherwise}\end{array}\right)$$

[a] Value truncated if fractional part was less than .5, rounded to next highest integer if fractional part was .5 or greater.

[b] $\frac{\text{Actual - Predicted}}{\text{Actual}} \times 100.$

to the manning in the 2521 and 2522 shops to arrive at a suitable relationship. The resulting relationship* is:

$$\left(\begin{array}{l}\text{Number of Personnel in Equipment}\\ \text{Maintenance and Inspection}\end{array}\right) = .12057 \left(\begin{array}{l}\text{Number of Personnel in}\\ \text{2521 and 2522 Work}\\ \text{Centers}\end{array}\right)$$

Standard Error of Estimate (adjusted)	=	2.32
Coefficient of Correlation (unadjusted)		.98
Coefficient of Variation (percent)		19.75
Mean Percent Y Deviation		15.26

This equation will be used in the model to estimate the total Equipment Maintenance and Inspection work center personnel requirements.

Reconnaissance Aircraft

When estimating Munitions Maintenance requirements, the aircraft are usually assumed to have a fighter or attack mission. However, TAC utilizes a number of reconnaissance aircraft (RF-4Cs, O-2s, and OV-10s) that also require Munitions Maintenance personnel. Though not primarily configured to carry missiles and bombs, these aircraft do have a limited armament package including guns, rockets, flares, and air-to-air missiles. For reconnaissance aircraft, the only major difference implied by the standards is for the 251X work centers. Instead of separate shops for weapons loading, gun services, and weapons release, only one combined work center--Weapons Branch, 251X--exists for reconnaissance aircraft. The standards for this shop are:

RF-4C, combat: constant manning = 12 per 18 UE squadron
O-2: hours = 308.83 + 19.58 (munitions sorties loaded)

---

*Because of the absence of certain data and the elimination of apparent outliers, 19 of the 27 possible data points were used to develop the equation.

Although the standards do not mention reconnaissance aircraft for the remaining work centers, it is clear from the authorizations in Table B.12 for the RF-4C that alternative methods are used to man the majority of Munitions Maintenance work centers for reconnaissance aircraft. Because of the sparsity of data points and the absence of additional information, Munitions Maintenance personnel can probably best be estimated on a personnel per aircraft basis. After review of the data in Table B.12, it was decided that manning will be allocated for reconnaissance aircraft on the basis of two slots per aircraft.

OVERHEAD AND SUPERVISION

The requirements for overhead and supervisorial personnel in the LCOM simulated shops are determined by TAC analysts using non-simulation techniques (usually by "operational audit"). A manning guide has been prepared that covers these positions in Organizational, Field, and Avionics Maintenance. Table B.14 presents the current requirements. The totals shown for Organizational, Field, and Avionics Squadrons are incorporated in MANPOWER.*

Manning for many of these shops is relatively insensitive to changes in the number of aircraft in the deployment unit. For example, End of Runway requires three persons, regardless of how many aircraft are deployed. One interesting consequence of these fixed requirements is that the number of locations to which a given number of aircraft will be deployed in wartime will affect the total personnel requirement. Thus, 48 aircraft going to two locations requires 60 supervisory and overhead personnel (2 times 30) in Organizational Maintenance, whereas only 46 people are required if the 48 aircraft are deployed to one location.

The only difference across aircraft types is in Avionics, where

---

*The overhead and supervisorial positions for Munitions Maintenance are discussed in the munitions section of this report. Some of the munitions overhead positions are determined using more complex standards than these here, which simply relate manning to UE.

Table B.14

OVERHEAD AND SUPERVISORY REQUIREMENTS FOR ORGANIZATIONAL, FIELD, AND AVIONICS MAINTENANCE

		Work Center	No. of UE Aircraft to Be Deployed												
			16	18	24	32	36	48	54	56	64	72	84	90[a]	96[a]
	Organizational Maintenance														
	2200	Command	2	2	3	3	3	4	4	4	4	4	4		
	2200	Technical Admin.	1	1	2	2	2	2	3	3	3	3	3		
	2210	Flight Line Maint.	2	2	2	2	2	3	3	3	3	3	3		
	2210	Line Chief	2	2	2	2	2	4	4	4	4	6	7		
	2210	Flight Chief	5	5	8	8	10	16	16	17	20	24	30		
	2210	Expeditor	3	3	3	4	4	6	6	7	9	9	11		
	2210	End of Runway	3	3	3	3	3	3	3	3	3	3	3		
	2220	Inspection	1	1	1	1	1	1	1	1	1	1	1		
	2230	Ground Support Equip.	1	1	1	1	1	1	1	1	1	1	1		
	2230	Bench Stock	2	2	2	2	2	2	2	2	2	3	3		
	2230	789 Equipment	2	2	3	3	3	4	4	4	4	4	4		
		Total	24	24	30	31	33	46	47	49	54	61	70	72	74
	Field Maintenance														
	2300	Command	1	1	1	1	1	1	1	1	1	1	1		
	2300	Maint. Supervision	2	2	2	2	2	3	3	3	3	3	4		
	2300	Technical Admin.	2	2	2	2	2	2	2	2	2	2	2		
		Fabrication Branch	1	1	1	1	1	1	1	1	1	1	1		
		Propulsion Branch	1	1	1	1	2	3	3	3	3	3	4		
		Bench Stock/Tool Room	3	3	3	3	3	3	4	5	5	6	7		
		Aero Systems Branch	1	1	1	1	2	2	2	2	2	2	3		
		Total	11	11	11	11	13	15	16	17	17	18	22	23	24
	Avionics Maintenance														
	2400	Command	1	1	1	1	1	1	1	1	1	1	1		
	2400	Maintenance Supervision	2	2	2	2	2	3	3	3	3	3	3		
	2400	Technical Admin.	1	1	1	2	2	2	2	2	2	2	2		
	2430	Avionics Flight Line Maint.	1	1	2	2	2	2	2	2	2	2	2		
	2436	Weapons Control/ Inertial Nav.	1	1	1	1	1	1	1	1	1	1	1		
b	2433	Auto. Flight Control Instr.	1	1	1	1	1	1	2	2	2	2	2		
	2460	Avionics Shop Maint.	1	1	2	2	2	2	2	2	2	2	2		
	2462	Auto. Test Station	0	0	0	0	0	1	1	1	1	1	1		
	2410	Commun./Nav.	1	1	1	1	1	2	2	2	2	2	2		
	2412	Navigation	1	1	1	1	1	1	1	1	1	1	1		
c	2420	Auto. Flight Control Instr.	1	1	1	1	1	1	2	2	2	2	2		
	2430	Mission Systems	1	1	1	1	1	2	2	2	2	2	2		
	2432	Weapons Control	1	1	1	1	1	1	1	1	1	2	2		
		Total(*b*)	8	8	10	11	12	13	14	14	14	14	14	14	14
		Total(*c*)	9	9	9	10	10	13	14	14	14	15	16	16	16

SOURCES: *Final Report, TAC Manpower Standards A-7D*, 4400MES/LC, Langley Air Force Base, Va., 18 June 1976, pp. 4-40 to 4-42 (the requirements in the A-7D report were summarized and extracted from another Hq. TAC/XPMM report); and *Standard Manpower Table, Avionics Maintenance Overhead/Supv Req (LCOM) (F-111, F-15 only)*, obtained at TAC Headquarters, Langley Air Force Base, September 1976.

[a]These estimates are linear extrapolations of the requirements.

[b]F-111, F-15 only (integrated avionics).

[c]Other aircraft (traditional avionics).

the F-111 and F-15 require slightly different numbers of personnel from all other aircraft (i.e., from the A-7D, F-4, and RF-4C). These differences are associated with integrated avionics systems. MANPOWER distinguishes between traditional and integrated avionics and allocates the appropriate number of personnel as shown in Table B.14.

The TAC manning guide allocates personnel for up to 84 aircraft. Since it may be necessary to generate manning for bases with as many as 96 aircraft, we have estimated requirements for 90 and 96 UE. The requirements for these deployments shown in Table B.14 are linear extrapolations of those for smaller deployments.

OFFICERS AND ENLISTED PERSONNEL REQUIREMENTS

The total number of officers and enlisted personnel for the entire fleet and for each deployment pattern is part of the output of MANPOWER.

The officer requirements in Organizational, Field, and Avionics Maintenance at a peacetime base depend on the number and size of the deployment units as depicted in Table B.15. This requirement is calculated in MANPOWER by summing the requirements for each deployment unit at the base. Note there is a slight difference between integrated and nonintegrated avionics officer requirements, which is incorporated in the model.

The number of officers in Chief of Maintenance equals four, plus one, two, or three, depending on the flying hours. The difference in flying hours corresponds roughly to one, two, and three squadrons. In MANPOWER, the rules listed in Table B.16 are incorporated.

The number of officers in the Munitions Maintenance Squadron equals three, plus zero, one, two, or three, depending on several factors. These factors are work orders processed, total personnel in Munitions Maintenance, and total personnel in Maintenance and Storage. Since these factors are all highly correlated with UE, in MANPOWER

Table B.15

NUMBER OF OFFICERS IN AVIONICS, FIELD, AND ORGANIZATIONAL MAINTENANCE SQUADRONS

	UE Deployed						
Squadron	16	18	24	32	36	48	
Organizational	2	2	3	3	3	5	
Field	2	2	2	2	3	5	
Avionics							
Integrated	2	2	4	4	4	5	
Nonintegrated	2	2	2	2	2	5	
Squadron	54	56	64	72	84	90	96
Organizational	6	6	6	6	6	6	7
Field	5	5	5	5	5	5	5
Avionics							
Integrated	5	5	5	5	5	5	5
Nonintegrated	5	5	5	5	5	5	5

SOURCES: Derived from *Final Report, TAC Manpower Standards A-7D*, 4400 MES/LC, Langley Air Force Base, Va., 18 June 1976, pp. 4-40 to 4-42 (the requirements in this A-7D report were extracted from another Hq TAC/XPMM report); and *Standard Manpower Table, Avionics Maintenance Overhead/Supv. Req. (LCOM) (F-111, F-15 only)*, at Hq. TAC, Langley Air Force Base, September 1976.

Table B.16

NUMBER OF OFFICERS IN CHIEF OF MAINTENANCE

UE Deployed	No. of Officers
UE $\leq$ 24	[illegible]
24 < UE < 54	6
UE $\geq$ 54	7

SOURCE: Derived from Department of the Air Force, *Manpower, TAC Manpower Standards*, TAC Regulation 26-3, 9 January 1976.

the number of Munitions Maintenance officers is a function of UE. The following rules are incorporated (Table B.17):

Table B.17

NUMBER OF OFFICERS IN MUNITIONS MAINTENANCE

UE Deployed	No. of Officers
UE < 24	3
24 ≤ UE < 48	4
48 ≤ UE < 64	5
UE ≥ 64	6

As with the officers in Organizational, Field, and Avionics Maintenance, the number of Chief of Maintenance and Munitions officers at a peacetime base equals the sum of the requirements for each deployment unit at the base.

Appendix C

DISTRIBUTION FACTORS RELATING TWO-DIGIT WORK UNIT CODE CATEGORIES TO FOUR MAJOR WORK CENTER AREAS

In MANPOWER, the personnel requirements in four work center areas (Flight Line, Field Maintenance, Jet Engine, and Avionics Maintenance) are predicted as a function of UE in the deployment unit, wartime sortie rate, and MMH/S for respective work center areas. In the first version of the model, the user supplied estimates of MMH/S for each of the four work center groups. The MMH/S for these four work center areas, however, are too highly aggregated to provide the analysis capability and information desired by the Cost Analysis Improvement Group (CAIG). They require the ability to input failure rates and repair times, at least at the subsystem level, to analyze the impact of changes in these factors on personnel requirements. Thus, MANPOWER has been expanded to accept reliability and maintainability factors for two-digit work unit code categories in addition to gross MMH/S in four work center areas.

In this appendix, we present results of examining the reliability and maintainability characteristics of two weapon systems, F-4E and F-15, at the two-digit work unit code level. The principal result is the distributions of base-level maintenance workloads (except those pertaining to aircraft support general) to the four work center areas for each two-digit work unit code category. These distributions can provide the basis for aggregating reliability and maintainability factors at the subsystem level to MMH/S for the four work center areas, which is one of the independent variables of the regression functions embedded in the MANPOWER model.

DATA AND ANALYSIS

Maintenance "hit analysis" data tapes were obtained from the 44th Management Engineering Squadron at Langley Air Force Base. These tapes contain a data base that provides inputs to the LCOM model.

The following data elements are in the hit analysis data tapes: For each on-equipment and off-equipment maintenance action recorded to the five-digit work unit code level, the tape contains the frequency of actions, average repair time, average elapsed time, team size, and AFSC utilized to accomplish the maintenance action in question.

The hit analysis data tapes were derived from AFM 66-1* data collected at Air Force bases during time periods indicated below:

Aircraft	Base	Data Collection
F-4E	Homestead, Eglin, and Seymour Johnson	Jan. 77 - June 77
F-15	Langley	Sept. 77 - Feb. 78

Although the hit analysis is a secondary data source, we feel that it is more reliable than unrefined raw data coming directly from the MDC (66-1).

Analysis entailed calculating the expected repair time per 100 sorties for each five-digit work unit code and keeping track of the relevant AFSCs. The expected repair times were aggregated to the two-digit work unit code level. Based on the known linkage between AFSCs and the four work center areas, the average maintenance man-hours were allocated among the work centers.

DISTRIBUTION OF MAINTENANCE WORKLOAD AMONG FOUR WORK CENTER AREAS

Tables C.1 and C.2 pertain to the F-4E, whereas Tables C.3 and C.4 concern the F-15. Tables C.1 and C.3 present the base-level maintenance manhours per 100 sorties in the four work center areas. As noted earlier, these manhours do not include maintenance actions stemming from aircraft support general. Assuming the average flying hours per sortie to be 1.5, the average MMH/FH are 24.9 and 25.5 for the F-4E and F-15, respectively. Tables C.2 and C.4 present the percentages of maintenance manhours in each two-digit work unit code that were performed in the four work center areas

---

*Hq. United States Air Force, *Maintenance Management*, AFM 66-1, Washington, D.C., 1 November 1975.

Table C.1

F-4E AVERAGE MANHOURS PER 100 SORTIES

Two-Digit Work Unit Code	Work Center Group: Flight Line and Inspection	Field Maintenance Shops	Jet Engine Shops	Avionics	Total
11 Air Frame	29.953	100.238	0.282	0.345	130.818
12 Cockpit and Fuselage Compartment	13.254	21.022	0.000	1.425	35.701
13 Landing Gear System	26.465	36.975	0.117	0.626	64.183
14 Flight Controls	29.904	64.771	0.013	2.513	97.201
16 Escape Capsule	0.000	0.020	0.000	0.000	0.020
23 Power Plant	3.479	6.118	83.547	4.324	97.468
24 Secondary Power System	0.000	0.000	0.000	0.012	0.012
41 Environmental Control	0.435	22.021	3.010	3.212	28.678
42 Electrical System	2.138	13.580	1.312	3.646	20.675
44 Lighting System	2.587	9.996	0.000	0.795	13.379
45 Hydraulic System	1.333	25.645	0.071	0.762	27.812
46 Fuel System	2.659	72.249	0.011	2.496	77.415
47 Oxygen System	0.634	14.080	0.000	0.000	14.714
49 Miscellaneous Utilities	0.389	4.796	0.000	0.000	5.185
51 Instruments	0.224	0.834	0.000	27.943	29.001
52 Auto Pilot	0.018	0.159	0.000	24.875	25.053
55 Malfunction Analysis	0.013	0.000	0.000	0.904	0.917
57 Guidance and Flight Cont.	0.000	0.000	0.000	0.000	0.000
61 HF Communications	0.000	0.000	0.000	0.000	0.000
62 VHF Communications	0.000	0.000	0.000	0.000	0.000
63 UHF Communications	0.000	0.000	0.000	0.000	0.000
64 Interphone	0.002	0.000	0.000	0.000	0.002
65 IFF System	0.000	0.000	0.000	0.000	0.000
69 Communication and Nav.	0.000	0.000	0.000	0.000	0.000
71 Radio Navigation	0.152	0.064	0.000	312.947	313.163
72 Radar Navigation	0.045	0.043	0.000	20.335	20.422
73 Bombing Navigation	0.062	0.048	0.000	75.263	75.372
74 Fire Control System	0.037	0.158	0.000	249.187	249.382
75 Weapons Delivery System	0.847	6.533	0.000	2.031	9.411
76 ECM	0.119	0.087	0.004	49.245	49.455
77 Photo/Reconnaissance	0.038	0.255	0.000	9.804	10.096
91 Emergency Equipment	0.000	0.431	0.000	0.000	0.431
92 TOW Target Equipment	0.085	0.227	0.000	0.000	0.312
93 Drag Chute Equipment	1.596	0.869	0.000	0.052	2.517
96 Personnel and Misc. Equip.	0.037	0.211	0.000	0.047	0.295
97 Explosive Devices	0.000	0.629	0.000	0.000	0.629

Table C.2

F-4E MANHOURS PERCENT PER WORK CENTER

Two-Digit Work Unit Code	Work Center Group			
	Flight Line Percent	Field Maintenance Percent	Jet Engine Percent	Avionics Percent
11 Air Frame	22.90	76.62	0.22	0.26
12 Cockpit and Fuselage Compartment	37.12	58.88	0.00	3.99
13 Landing Gear System	41.23	57.61	0.18	0.98
14 Flight Controls	30.77	66.64	0.01	2.58
16 Escape Capsule	0.00	100.00	0.00	0.00
23 Power Plant	3.57	6.28	85.72	4.44
24 Secondary Power System	0.00	0.00	0.00	100.00
41 Environmental Control	1.52	76.79	10.50	11.20
42 Electrical System	10.34	65.68	6.35	17.63
44 Lighting System	19.34	74.72	0.00	5.94
45 Hydraulic System	4.79	92.21	0.26	2.74
46 Fuel System	3.43	93.33	0.01	3.22
47 Oxygen System	4.31	95.69	0.00	0.00
49 Miscellaneous Utilities	7.50	92.50	0.00	0.00
51 Instruments	0.77	2.87	0.00	96.35
52 Auto Pilot	0.07	0.64	0.00	99.29
55 Malfunction Analysis	1.47	0.00	0.00	98.53
57 Guidance and Flight Cont.	0.00	0.00	0.00	0.00
61 HF Communications	0.00	0.00	0.00	0.00
62 VHF Communications	0.00	0.00	0.00	0.00
63 UHF Communications	0.00	0.00	0.00	0.00
64 Interphone	100.00	0.00	0.00	0.00
65 IFF System	0.00	0.00	0.00	0.00
69 Communication and Nav.	0.00	0.00	0.00	0.00
71 Radio Navigation	0.05	0.02	0.00	99.93
72 Radar Navigation	0.22	0.21	0.00	99.57
73 Bombing Navigation	0.08	0.06	0.00	99.86
74 Fire Control System	0.01	0.06	0.00	99.92
75 Weapons Delivery System	9.00	69.42	0.00	21.59
76 ECM	0.24	0.18	0.01	99.57
77 Photo/Reconnaissance	0.37	2.52	0.00	97.10
91 Emergency Equipment	0.00	100.00	0.00	0.00
92 TOW Target Equipment	27.28	72.72	0.00	0.00
93 Drag Chute Equipment	63.40	34.52	0.00	2.08
96 Personnel and Misc. Equip.	12.40	71.52	0.00	16.08
97 Explosive Devices	0.00	100.00	0.00	0.00

Table C.3

F-15 AVERAGE MANHOURS PER 100 SORTIES

Two-Digit Work Unit Code	Flight Line and Inspection	Field Maintenance Shops	Jet Engine Shops	Avionics	Total
	Work Center Group				
11 Air Frame	32.747	170.604	0.000	13.731	217.082
12 Cockpit and Fuselage Compartment	14.252	27.383	0.000	2.618	44.253
13 Landing Gear System	30.227	82.348	0.000	1.474	114.048
14 Flight Controls	24.931	45.661	0.000	4.105	74.697
16 Escape Capsule	0.000	0.224	0.000	0.000	0.224
23 Power Plant	5.994	14.456	198.736	5.446	224.632
24 Secondary Power System	2.600	5.194	24.941	0.256	32.991
41 Environmental Control	1.133	20.447	0.067	1.007	22.654
42 Electrical System	0.573	16.682	0.378	9.994	27.626
44 Lighting System	2.061	17.734	0.000	3.396	23.190
45 Hydraulic System	1.195	40.769	0.000	4.738	46.702
46 Fuel System	0.718	53.502	0.171	5.492	59.883
47 Oxygen System	0.386	4.551	0.000	1.177	6.113
49 Miscellaneous Utilities	0.246	3.500	0.000	0.015	3.761
51 Instruments	0.203	0.859	0.000	26.951	28.013
52 Auto Pilot	0.018	0.121	0.000	21.315	21.455
55 Malfunction Analysis	0.023	0.295	0.000	4.557	4.876
57 Guidance and Flight Cont.	0.005	0.000	0.000	7.894	7.899
61 HF Communications	0.000	0.000	0.000	0.000	0.000
62 VHF Communications	0.000	0.000	0.000	0.000	0.000
63 UHF Communications	0.066	0.244	0.000	51.300	51.610
64 Interphone	0.000	0.000	0.000	0.000	0.000
65 IFF System	0.021	0.061	0.000	44.818	44.901
69 Communication and Nav.	0.000	0.000	0.000	0.000	0.000
71 Radio Navigation	0.048	0.282	0.000	69.346	69.677
72 Radar Navigation	0.000	0.000	0.000	0.000	0.000
73 Bombing Navigation	0.000	0.000	0.000	0.032	0.032
74 Fire Control System	0.556	0.604	0.000	372.258	373.419
75 Weapons Delivery System	0.306	5.643	0.000	6.602	12.551
76 ECM	0.318	0.370	0.000	16.934	17.622
77 Photo/Reconnaissance	0.000	0.020	0.000	0.000	0.020
91 Emergency Equipment	0.162	0.506	0.000	0.030	0.698
92 TOW Target Equipment	0.000	0.000	0.000	0.000	0.000
93 Drag Chute Equipment	0.000	0.000	0.000	0.448	0.448
96 Personnel and Misc. Equip.	0.000	0.000	0.000	0.000	0.000
97 Explosive Devices	0.000	0.303	0.000	0.000	0.303

Table C.4

F-15 MANHOURS PERCENT PER WORK CENTER

Two-Digit Work Unit Code	Work Center Group: Flight Line Percent	Field Maintenance Percent	Jet Engine Percent	Avionics Percent
11 Air Frame	15.08	78.59	0.00	6.33
12 Cockpit and Fuselage Compartment	32.21	61.88	0.00	5.92
13 Landing Gear System	26.50	72.20	0.00	1.29
14 Flight Controls	33.38	61.13	0.00	5.50
16 Escape Capsule	0.00	100.00	0.00	0.00
23 Power Plant	2.67	6.44	88.47	2.42
24 Secondary Power System	7.88	15.74	75.60	0.78
41 Environmental Control	5.00	90.26	0.30	4.44
42 Electrical System	2.07	60.38	1.37	36.18
44 Lighting System	8.89	76.47	0.00	14.64
45 Hydraulic System	2.56	87.30	0.00	10.15
46 Fuel System	1.20	89.34	0.29	9.17
47 Oxygen System	6.31	74.44	0.00	19.25
49 Miscellaneous Utilities	6.53	93.08	0.00	0.39
51 Instruments	0.73	3.07	0.00	96.21
52 Auto Pilot	0.09	0.56	0.00	99.35
55 Malfunction Analysis	0.47	6.06	0.00	93.47
57 Guidance and Flight Cont.	0.06	0.00	0.00	99.94
61 HF Communications	0.00	0.00	0.00	0.00
62 VHF Communications	0.00	0.00	0.00	0.00
63 UHF Communications	0.13	0.47	0.00	99.40
64 Interphone	0.00	0.00	0.00	0.00
65 IFF System	0.05	0.14	0.00	99.82
69 Communication and Nav.	0.00	0.00	0.00	0.00
71 Radio Navigation	0.07	0.41	0.00	99.53
72 Radar Navigation	0.00	0.00	0.00	0.00
73 Bombing Navigation	0.00	0.00	0.00	100.00
74 Fire Control System	0.15	0.16	0.00	99.69
75 Weapons Delivery System	2.44	44.96	0.00	52.60
76 ECM	1.81	2.10	0.00	96.10
77 Photo/Reconnaissance	0.00	100.00	0.00	0.00
91 Emergency Equipment	23.21	72.49	0.00	4.30
92 TOW Target Equipment	0.00	0.00	0.00	0.00
93 Drag Chute Equipment	0.00	0.00	0.00	100.00
96 Personnel and Misc. Equip.	0.00	0.00	0.00	0.00
97 Explosive Devices	0.00	100.00	0.00	0.00

Appendix D

MANPOWER VALIDATION

The model described in this report is the second version of MANPOWER. The original was completed in December 1977 and installed on Department of Defense computers. The present version incorporates modifications based on validation runs using new F-4E and A-10 data. The results of these validations and the subsequent changes in MANPOWER are described in this appendix.

VALIDATION RESULTS

Table D.1 displays the detailed personnel requirements for the A-10 that have been stipulated by the Tactical Air Command XPM and those predicted by version one of MANPOWER. Overall, the two sets of requirements are acceptably close.

Table D.2 shows the total personnel requirements for several F-4E deployments of various sizes operated at low, medium, and high sortie rates. Version one of MANPOWER tended to underestimate the requirement at the lower sortie rates and overestimate it at the higher rates.

MODIFICATIONS IN MANPOWER

Analysis of the differences at the work center level between the TAC requirements and MANPOWER predictions indicated a number of areas where improvements in the model could be made. The following actions were taken.

1. The original set of equations for the LCOM shops was too sensitive to the sortie rate. This caused overmanning at high rates and undermanning at low rates. New equations were developed that incorporated the new data for the A-10 and F-4E (the old F-4E data were removed). The range of sortie rates in the new data base is .64 to 1.36 (the old range was .67 to .99). The new equations have lower

Table D.1

A-10 MAINTENANCE PERSONNEL REQUIREMENTS: STIPULATED BY TAC XPM[a] AND PREDICTED BY MANPOWER

Work Center	24 UE			48UE		
	TAC	MANPOWER	Difference	TAC	MANPOWER	Difference
Chief of Maintenance	60	64	+4	105	92	-13
Organizational Maintenance						
Flight Line and Inspection (LCOM)	47	46	-1	82	82	0
Overhead and Supervision	43	30	-13	70	46	-24
Total	90	76	-14	152	128	-24
Field Maintenance						
Aerospace Systems (LCOM)	46	40	-6	58	56	-2
Jet Engine (LCOM)	24	25	+1	51	56	+5
Nonsimulated	34	59	+25	44	104	+60
Overhead and Supervision	10	11	+1	16	15	-1
Total	114	135	+21	169	231	+62
Avionics Maintenance						
Avionics Shops (LCOM)	42	30	-12	51	44	-7
Nonsimulated	10	33	+23	20	43	+23
Overhead and Supervision	8	9	+1	12	13	+1
Total	60	72	+12	83	100	+17
Munitions Maintenance						
Munitions Services	80	76	-4	136	152	+16
Munitions Maintenance	43	40	-3	73	81	+8
Overhead and Supervision	14	26	+12	23	31	+8
Total	137	142	+5	232	264	+32
Grand Total	461	489	+28 (+6.1%)	741	815	+74 (+10.0%)

[a]SOURCE Directorate of Manpower and Organization, Tactical Air Command Headquarters, Langley Air Force Base, Va.

Table D.2

F-4E MAINTENANCE PERSONNEL REQUIREMENTS: STIPULATED BY TAC XPM AND PREDICTED BY MANPOWER

No. of UE Deployed	Sortie Rate	Personnel Requirement		Difference	
		TAC	MANPOWER	Number	Percent
18	.70	448	424	-24	-5.4
24	.64	521	469	-52	-10.0
48	.76	875	813	-62	-7.1
72	.74	1263	1077	-186	-14.7
18	.90	476	528	+52	+10.9
24	.98	585	666	+81	+13.8
48	1.11	1052	1200	+148	+14.1
72	1.06	1507	1526	+19	+1.3
18	1.02	485	593	+108	+22.3
24	1.18	623	818	+195	+31.3
48	1.22	1125	1349	+224	+19.9
72	1.36	1730	2073	+343	+19.8

coefficients for the sortie rate which results in smaller changes in manning in response to changes in the value of this variable.

2. Repair and Reclamation has been included with the Aerospace Systems Shops and Structural Repair as an LCOM simulated shop. Previously, it was manned according to a TAC standard.

3. Minimum manning has been set at six positions per LCOM shop in Field and Avionics Maintenance. Previously, MANPOWER provided no minimum manning in these shops except that implied by the constant value in the manning equations. However, because at low levels of workload MANPOWER consistently underestimated the requirement (see, for example, Avionics Shops for the A-10), an explicit minimum has been implemented. Six positions per shop reflects observed minimums in many of the low workload shops of the A-10, F-4E, and other TAC aircraft.

4. Variation between aircraft in the number of shops in Avionics Maintenance led to making this variable a user input.
5. A Precision Measurement Equipment Laboratory personnel requirement (of 23) was originally included in the model. However, since this shop is occasionally not included with TAC requirements (it is assigned a different program element code from that of the aircraft), and is usually allocated to three squadron wings only (not to deployment units), it has been eliminated from MANPOWER program totals.
6. The large difference between the TAC requirements and the MANPOWER predictions for "nonsimulated" Field Maintenance Shops for the A-10 (see Table D.1) was traced to the requirements for Aerospace Ground Equipment. Inquiries at TAC headquarters revealed that their original requirements for A-10 AGE maintenance were much too low. The revised requirements were close enough to those generated by MANPOWER to warrant not changing the model.
7. The TAC requirement for the A-10 includes an allocation for "alert crew" in the Overhead and Supervision category of Organizational Maintenance. Equal to one position per alert aircraft, this allocation has been incorporated in MANPOWER as a user option.

Appendix E

LOGISTICS COMPOSITE MODEL DATA BASE

MDS	WORK CENTER	UE	MANNING	SORTIE RATE	MMH/S
A7D	22XX	24	83	.87	16.7
A7D	22XX	48	140	.87	15.5
A7D	22XX	72	194	.87	15.3
A7D	2323	24	12	.87	2.1
A7D	2323	48	21	.87	2.3
A7D	2323	72	30	.87	2.5
A7D	2313	24	8	.87	1.1
A7D	2313	48	9	.87	1.0
A7D	2313	72	14	.87	1.0
A7D	2332	24	5	.87	0.5
A7D	2332	48	8	.87	0.5
A7D	2332	72	11	.87	0.5
A7D	2333	24	12	.87	1.6
A7D	2333	48	14	.87	1.6
A7D	2333	72	20	.87	1.7
A7D	2334	24	12	.87	2.1
A7D	2334	48	18	.87	2.2
A7D	2334	72	27	.87	2.2
A7D	2336	24	8	.87	0.9
A7D	2336	48	9	.87	0.9
A7D	2336	72	11	.87	0.9
A7D	2339	24	6	.87	0.7
A7D	2339	48	6	.87	0.7
A7D	2339	72	9	.87	0.7
A7D	2411	24	6	.87	0.9
A7D	2411	48	8	.87	0.9
A7D	2411	72	11	.87	0.8
A7D	2412	24	6	.87	1.0
A7D	2412	48	8	.87	0.9
A7D	2412	72	12	.87	0.9
A7D	2414	24	8	.87	1.3
A7D	2414	48	12	.87	1.4
A7D	2414	72	18	.87	1.6
A7D	2421	24	8	.87	1.0
A7D	2421	48	11	.87	0.9
A7D	2421	72	12	.87	0.8
A7D	2422	24	9	.87	1.4
A7D	2422	48	11	.87	1.4
A7D	2422	72	17	.87	1.2
A7D	2432	24	15	.87	3.1
A7D	2432	48	26	.87	2.9
A7D	2432	72	36	.87	3.2
A7D	2434	24	5	.87	0.6
A7D	2434	48	6	.87	0.6
A7D	2434	72	8	.87	0.6

MDS	WORK CENTER	UE	MANNING	SORTIE RATE	MMH/S
A10	22XX	24	46	.90	8.4
A10	22XX	48	82	.93	8.3
A10	2323	24	24	.90	3.8
A10	2323	48	51	.93	4.6
A10	2313	24	8	.90	.7
A10	2313	48	9	.93	.8
A10	2331	24	9	.90	.7
A10	2331	48	9	.93	.7
A10	2332	24	9	.90	.1
A10	2332	48	9	.93	.1
A10	2333	24	6	.90	1.2
A10	2333	48	10	.93	1.1
A10	2334	24	6	.90	.6
A10	2334	48	8	.93	.5
A10	2336	24	6	.90	.5
A10	2336	48	6	.93	.4
A10	2339	24	5	.90	.1
A10	2339	48	5	.93	.1
A10	2411	24	5	.90	.2
A10	2411	48	5	.93	.2
A10	2412	24	5	.90	.1
A10	2412	48	5	.93	.1
A10	2413	24	6	.90	1.2
A10	2413	48	6	.93	1.1
A10	2421	24	5	.90	.1
A10	2421	48	5	.93	.1
A10	2422	24	6	.90	1.0
A10	2422	48	10	.93	1.0
A10	2432	24	6	.90	.7
A10	2432	48	7	.93	.6
A10	2434	24	2	.90	.1
A10	2434	48	2	.93	.1
A10	2435	24	5	.90	.2
A10	2435	48	5	.93	.2

MDS	WORK CENTER	UE	MANNING	SORTIE RATE	MMH/S
F111D	22XX	24	98	.70	25.5
F111D	22XX	48	184	.70	25.3
F111D	2323	24	34	.70	7.9
F111D	2323	48	65	.70	9.2
F111D	2313	24	15	.70	3.1
F111D	2313	48	27	.70	3.9
F111D	2332	24	12	.70	1.3
F111D	2332	48	12	.70	1.7
F111D	2333	24	16	.70	3.3
F111D	2333	48	27	.70	3.6
F111D	2334	24	20	.70	4.2
F111D	2334	48	34	.70	4.7
F111D	2336	24	16	.70	4.2
F111D	2336	48	31	.70	4.6
F111D	2339	24	7	.70	0.8
F111D	2339	48	7	.70	0.9
F111D	2400	24	97	.70	24.8
F111D	2400	48	169	.70	24.1
F111D	2462	24	55	.70	9.4
F111D	2462	48	91	.70	9.3
F111D	2463	24	30	.70	3.3
F111D	2463	48	47	.70	3.4

MDS	WORK CENTER	UE	MANNING	SORTIE RATE	MMH/S
RF4C	22XX	18	44	.67	18.1
RF4C	22XX	36	69	.67	16.5
RF4C	22XX	54	96	.67	15.0
RF4C	2323	18	24	.67	11.0
RF4C	2323	36	39	.67	8.9
RF4C	2323	54	56	.67	9.4
RF4C	2313	18	8	.67	2.6
RF4C	2313	36	11	.67	2.7
RF4C	2313	54	15	.67	2.5
RF4C	2332	18	9	.67	3.7
RF4C	2332	36	18	.67	4.3
RF4C	2332	54	30	.67	4.9
RF4C	2333	18	5	.67	1.5
RF4C	2333	36	6	.67	1.4
RF4C	2333	54	8	.67	1.3
RF4C	2334	18	6	.67	2.1
RF4C	2334	36	9	.67	2.0
RF4C	2334	54	11	.67	2.0
RF4C	2336	18	6	.67	1.3
RF4C	2336	36	6	.67	1.3
RF4C	2336	54	9	.67	1.5
RF4C	2339	18	8	.67	1.5
RF4C	2339	36	9	.67	1.6
RF4C	2339	54	11	.67	1.5
RF4C	2411	18	3	.67	0.7
RF4C	2411	36	4	.67	0.8
RF4C	2411	54	5	.67	0.8
RF4C	2412	18	5	.67	1.9
RF4C	2412	36	8	.67	1.7
RF4C	2412	54	12	.67	1.8
RF4C	2414	18	9	.67	3.7
RF4C	2414	36	15	.67	3.6
RF4C	2414	54	21	.67	3.5
RF4C	2421	18	3	.67	0.6
RF4C	2421	36	3	.67	0.6
RF4C	2421	54	4	.67	0.6
RF4C	2422	18	5	.67	1.1
RF4C	2422	36	5	.67	1.1
RF4C	2422	54	7	.67	1.1
RF4C	2434	18	31	.67	10.9
RF4C	2434	36	39	.67	10.4
RF4C	2434	54	57	.67	9.9

* MDS	WORK CENTER	UE	MANNING	SORTIE RATE	MMH/S
F4E(73)	22XX	24	105	.96	16.0
F4E(73)	22XX	48	160	.96	16.1
F4E(73)	22XX	72	211	.96	16.0
F4E(73)	2323	24	39	.96	4.5
F4E(73)	2323	48	56	.96	4.4
F4E(73)	2323	72	76	.96	4.6
F4E(73)	2313	24	6	.96	1.0
F4E(73)	2313	48	9	.96	1.2
F4E(73)	2313	72	12	.96	1.1
F4E(73)	2332	24	12	.96	1.9
F4E(73)	2332	48	21	.96	2.0
F4E(73)	2332	72	24	.96	2.1
F4E(73)	2333	24	9	.96	0.8
F4E(73)	2333	48	13	.96	0.8
F4E(73)	2333	72	16	.96	0.9
F4E(73)	2334	24	8	.96	0.8
F4E(73)	2334	48	9	.96	0.8
F4E(73)	2334	72	10	.96	0.9
F4E(73)	2336	24	9	.96	0.9
F4E(73)	2336	48	15	.96	1.1
F4E(73)	2336	72	18	.96	1.0
F4E(73)	2339	24	12	.96	0.8
F4E(73)	2339	48	18	.96	1.0
F4E(73)	2339	72	21	.96	1.0
F4E(73)	2411	24	6	.96	0.9
F4E(73)	2411	48	9	.96	0.9
F4E(73)	2411	72	12	.96	0.9
F4E(73)	2412	24	6	.96	0.8
F4E(73)	2412	48	8	.96	0.8
F4E(73)	2412	72	10	.96	0.8
F4E(73)	2414	24	8	.96	1.2
F4E(73)	2414	48	12	.96	1.4
F4E(73)	2414	72	16	.96	1.2
F4E(73)	2421	24	6	.96	0.4
F4E(73)	2421	48	8	.96	0.5
F4E(73)	2421	72	9	.96	0.4
F4E(73)	2422	24	10	.96	1.2
F4E(73)	2422	48	15	.96	1.1
F4E(73)	2422	72	18	.96	1.0
F4E(73)	2432	24	33	.96	4.8
F4E(73)	2432	48	45	.96	4.5
F4E(73)	2432	72	57	.96	4.6
F4E(73)	2434	24	2	.96	0.1
F4E(73)	2434	48	2	.96	0.1
F4E(73)	2434	72	3	.96	0.1

*
1973 LCOM STUDY.

* MDS	WORK CENTER	UE	MANNING	SORTIE RATE	MMH/S
F4E(78)	22XX	18	47	.70	12.3
F4E(78)	22XX	18	54	.90	12.1
F4E(78)	22XX	18	57	1.02	12.4
F4E(78)	22XX	24	53	.64	12.5
F4E(78)	22XX	24	68	.98	12.0
F4E(78)	22XX	24	75	1.18	11.6
F4E(78)	22XX	36	73	.73	11.8
F4E(78)	22XX	36	94	1.01	11.3
F4E(78)	22XX	36	109	1.21	11.0
F4E(78)	22XX	48	87	.76	10.7
F4E(78)	22XX	48	124	1.11	10.8
F4E(78)	22XX	48	140	1.22	10.7
F4E(78)	22XX	72	127	.74	11.1
F4E(78)	22XX	72	174	1.06	10.4
F4E(78)	22XX	72	222	1.36	10.6
F4E(78)	2323	18	12	.70	4.6
F4E(78)	2323	18	29	.90	6.7
F4E(78)	2323	18	34	1.02	6.7
F4E(78)	2323	24	21	.64	6.4
F4E(78)	2323	24	33	.98	6.7
F4E(78)	2323	24	43	1.18	7.2
F4E(78)	2323	36	33	.73	5.9
F4E(78)	2323	36	65	1.01	7.6
F4E(78)	2323	36	75	1.21	7.3
F4E(78)	2323	48	52	.76	6.8
F4E(78)	2323	48	87	1.11	7.8
F4E(78)	2323	48	103	1.22	7.8
F4E(78)	2323	72	82	.74	7.3
F4E(78)	2323	72	130	1.06	7.7
F4E(78)	2323	72	168	1.36	7.7
F4E(78)	2313	18	9	.70	2.9
F4E(78)	2313	18	12	.90	3.1
F4E(78)	2313	18	13	1.02	3.2
F4E(78)	2313	24	10	.64	2.9
F4E(78)	2313	24	15	.98	3.0
F4E(78)	2313	24	19	1.18	3.2
F4E(78)	2313	36	17	.73	3.0

* 1978 LCOM STUDY.

MDS	WORK CENTER	UE	MANNING	SORTIE RATE	MMH/S
F4E(78)	2313	36	24	1.01	3.0
F4E(78)	2313	36	29	1.21	3.0
F4E(78)	2313	48	23	.76	2.9
F4E(78)	2313	48	33	1.11	3.0
F4E(78)	2313	48	41	1.22	3.1
F4E(78)	2313	72	35	.74	3.0
F4E(78)	2313	72	51	1.06	3.0
F4E(78)	2313	72	66	1.36	3.1
F4E(78)	2331	18	18	.70	1.5
F4E(78)	2331	18	18	.90	1.6
F4E(78)	2331	18	18	1.02	1.6
F4E(78)	2331	24	18	.64	1.7
F4E(78)	2331	24	18	.98	1.6
F4E(78)	2331	24	18	1.18	1.7
F4E(78)	2331	36	18	.73	1.6
F4E(78)	2331	36	18	1.01	1.5
F4E(78)	2331	36	21	1.21	1.5
F4E(78)	2331	48	18	.76	1.5
F4E(78)	2331	48	22	1.11	1.6
F4E(78)	2331	48	26	1.22	1.6
F4E(78)	2331	72	21	.74	1.6
F4E(78)	2331	72	30	1.06	1.6
F4E(78)	2331	72	34	1.36	1.5
F4E(78)	2332	18	7	.70	2.3
F4E(78)	2332	18	9	.90	2.2
F4E(78)	2332	18	10	1.02	2.3
F4E(78)	2332	24	7	.64	2.2
F4E(78)	2332	24	11	.98	2.2
F4E(78)	2332	24	14	1.18	2.3
F4E(78)	2332	36	13	.73	2.2
F4E(78)	2332	36	19	1.01	2.2
F4E(78)	2332	36	22	1.21	2.3
F4E(78)	2332	48	17	.76	2.2
F4E(78)	2332	48	25	1.11	2.2
F4E(78)	2332	48	30	1.22	2.2
F4E(78)	2332	72	25	.74	2.2
F4E(78)	2332	72	37	1.06	2.2
F4E(78)	2332	72	48	1.36	2.2
F4E(78)	2333	18	6	.70	1.0
F4E(78)	2333	18	6	.90	1.0
F4E(78)	2333	18	6	1.02	1.0
F4E(78)	2333	24	6	.64	1.0
F4E(78)	2333	24	6	.98	.9
F4E(78)	2333	24	6	1.18	1.0

MDS	WORK CENTER	UE	MANNING	SORTIE RATE	MMH/S
F4E(78)	2333	36	6	.73	.9
F4E(78)	2333	36	8	1.01	1.0
F4E(78)	2333	36	10	1.21	1.0
F4E(78)	2333	48	8	.76	.9
F4E(78)	2333	48	11	1.11	.9
F4E(78)	2333	48	13	1.22	1.0
F4E(78)	2333	72	11	.74	.9
F4E(78)	2333	72	16	1.06	1.0
F4E(78)	2333	72	22	1.36	1.0
F4E(78)	2334	18	9	.70	1.5
F4E(78)	2334	18	9	.90	1.6
F4E(78)	2334	18	9	1.02	1.6
F4E(78)	2334	24	9	.64	1.6
F4E(78)	2334	24	9	.98	1.5
F4E(78)	2334	24	9	1.18	1.5
F4E(78)	2334	36	9	.73	1.5
F4E(78)	2334	36	12	1.01	1.6
F4E(78)	2334	36	15	1.21	1.5
F4E(78)	2334	48	12	.76	1.5
F4E(78)	2334	48	17	1.11	1.5
F4E(78)	2334	48	21	1.22	1.6
F4E(78)	2334	72	17	.74	1.5
F4E(78)	2334	72	27	1.06	1.6
F4E(78)	2334	72	32	1.36	1.5
F4E(78)	2336	18	6	.70	.4
F4E(78)	2336	18	6	.90	.4
F4E(78)	2336	18	6	1.02	.4
F4E(78)	2336	24	6	.64	.4
F4E(78)	2336	24	6	.98	.4
F4E(78)	2336	24	6	1.18	.4
F4E(78)	2336	36	6	.73	.4
F4E(78)	2336	36	6	1.01	.4
F4E(78)	2336	36	6	1.21	.4
F4E(78)	2336	48	6	.76	.4
F4E(78)	2336	48	6	1.11	.4
F4E(78)	2336	48	6	1.22	.4
F4E(78)	2336	72	6	.74	.4
F4E(78)	2336	72	7	1.06	.4
F4E(78)	2336	72	9	1.36	.4
F4E(78)	2339	18	9	.70	.6
F4E(78)	2339	18	9	.90	.6
F4E(78)	2339	18	9	1.02	.7
F4E(78)	2339	24	9	.64	.6
F4E(78)	2339	24	9	.98	.6
F4E(78)	2339	24	9	1.18	.6

MDS	WORK CENTER	UE	MANNING	SORTIE RATE	MMH/S
F4E(78)	2339	36	9	.73	.6
F4E(78)	2339	36	9	1.01	.6
F4E(78)	2339	36	9	1.21	.6
F4E(78)	2339	48	9	.76	.6
F4E(78)	2339	48	9	1.11	.6
F4E(78)	2339	48	9	1.22	.6
F4E(78)	2339	72	9	.74	.5
F4E(78)	2339	72	10	1.06	.5
F4E(78)	2339	72	13	1.36	.5
F4E(78)	2403	18	6	.70	.4
F4E(78)	2403	18	6	.90	.5
F4E(78)	2403	18	6	1.02	.5
F4E(78)	2411	18	6	.70	1.9
F4E(78)	2411	18	6	.90	1.7
F4E(78)	2411	18	7	1.02	1.7
F4E(78)	2412	18	6	.70	.7
F4E(78)	2412	18	6	.90	.6
F4E(78)	2412	18	6	1.02	.6
F4E(78)	2413	18	9	.70	2.2
F4E(78)	2413	18	9	.90	2.2
F4E(78)	2413	18	9	1.02	2.2
F4E(78)	2414	18	6	.70	1.2
F4E(78)	2414	18	6	.90	1.2
F4E(78)	2414	18	6	1.02	1.2
F4E(78)	2421	18	6	.70	.5
F4E(78)	2421	18	6	.90	.4
F4E(78)	2421	18	6	1.02	.5
F4E(78)	2422	18	6	.70	.9
F4E(78)	2422	18	6	.90	1.0
F4E(78)	2422	18	6	1.02	1.0
F4E(78)	2432	18	13	.70	4.1
F4E(78)	2432	18	17	.90	4.5
F4E(78)	2432	18	17	1.02	4.4
F4E(78)	2434	18	6	.70	.4
F4E(78)	2434	18	6	.90	.4
F4E(78)	2434	18	6	1.02	.4
F4E(78)	2403	24	6	.64	.4
F4E(78)	2403	24	6	.98	.5
F4E(78)	2403	24	6	1.18	.5
F4E(78)	2411	24	6	.64	1.8
F4E(78)	2411	24	9	.98	1.8
F4E(78)	2411	24	10	1.18	1.6
F4E(78)	2412	24	6	.64	.6
F4E(78)	2412	24	6	.98	.6
F4E(78)	2412	24	6	1.18	.6

MDS	WORK CENTER	UE	MANNING	SORTIE RATE	MMH/S
F4E(78)	2413	24	9	.64	2.2
F4E(78)	2413	24	11	.98	2.2
F4E(78)	2413	24	13	1.18	2.2
F4E(78)	2414	24	6	.64	1.2
F4E(78)	2414	24	6	.98	1.2
F4E(78)	2414	24	7	1.18	1.1
F4E(78)	2421	24	6	.64	.4
F4E(78)	2421	24	6	.98	.5
F4E(78)	2421	24	6	1.18	.5
F4E(78)	2422	24	6	.64	1.0
F4E(78)	2422	24	6	.98	1.0
F4E(78)	2422	24	6	1.18	1.0
F4E(78)	2432	24	14	.64	4.2
F4E(78)	2432	24	22	.98	4.4
F4E(78)	2432	24	28	1.18	4.6
F4E(78)	2434	24	6	.64	.4
F4E(78)	2434	24	6	.98	.4
F4E(78)	2434	24	6	1.18	.4
F4E(78)	2403	36	6	.73	.4
F4E(78)	2403	36	6	1.01	.4
F4E(78)	2403	36	6	1.21	.4
F4E(78)	2411	36	10	.73	1.7
F4E(78)	2411	36	12	1.01	1.6
F4E(78)	2411	36	16	1.21	1.5
F4E(78)	2412	36	6	.73	.6
F4E(78)	2412	36	6	1.01	.6
F4E(78)	2412	36	7	1.21	.6
F4E(78)	2413	36	13	.73	2.2
F4E(78)	2413	36	17	1.01	2.2
F4E(78)	2413	36	21	1.21	2.2
F4E(78)	2414	36	7	.73	1.2
F4E(78)	2414	36	9	1.01	1.2
F4E(78)	2414	36	12	1.21	1.2
F4E(78)	2421	36	6	.73	.4
F4E(78)	2421	36	6	1.01	.4
F4E(78)	2421	36	6	1.21	.5
F4E(78)	2422	36	6	.73	.9
F4E(78)	2422	36	8	1.01	.9
F4E(78)	2422	36	10	1.21	1.0
F4E(78)	2432	36	25	.73	4.5
F4E(78)	2432	36	35	1.01	4.4
F4E(78)	2432	36	44	1.21	4.4
F4E(78)	2434	36	6	.73	.4
F4E(78)	2434	36	6	1.01	.5
F4E(78)	2434	36	6	1.21	.4

MDS	WORK CENTER	UE	MANNING	SORTIE RATE	MMH/S
F4E(78)	2403	48	6	.76	.4
F4E(78)	2403	48	6	1.11	.4
F4E(78)	2403	48	6	1.22	.4
F4E(78)	2411	48	13	.76	1.7
F4E(78)	2411	48	17	1.11	1.5
F4E(78)	2411	48	21	1.22	1.5
F4E(78)	2412	48	6	.76	.7
F4E(78)	2412	48	7	1.11	.6
F4E(78)	2412	48	9	1.22	.6
F4E(78)	2413	48	18	.76	2.3
F4E(78)	2413	48	26	1.11	2.3
F4E(78)	2413	48	30	1.22	2.3
F4E(78)	2414	48	9	.76	1.1
F4E(78)	2414	48	13	1.11	1.2
F4E(78)	2414	48	16	1.22	1.1
F4E(78)	2421	48	6	.76	.5
F4E(78)	2421	48	6	1.11	.5
F4E(78)	2421	48	7	1.22	.5
F4E(78)	2422	48	8	.76	1.0
F4E(78)	2422	48	11	1.11	.9
F4E(78)	2422	48	13	1.22	1.0
F4E(78)	2432	48	34	.76	4.4
F4E(78)	2432	48	49	1.11	4.4
F4E(78)	2432	48	62	1.22	4.6
F4E(78)	2434	48	6	.76	.4
F4E(78)	2434	48	6	1.11	.4
F4E(78)	2434	48	6	1.22	.4
F4E(78)	2403	72	6	.74	.3
F4E(78)	2403	72	6	1.06	.4
F4E(78)	2403	72	9	1.36	.4
F4E(78)	2411	72	18	.74	1.6
F4E(78)	2411	72	26	1.06	1.5
F4E(78)	2411	72	32	1.36	1.5
F4E(78)	2412	72	8	.74	.6
F4E(78)	2412	72	11	1.06	.6
F4E(78)	2412	72	14	1.36	.7
F4E(78)	2413	72	25	.74	2.2
F4E(78)	2413	72	37	1.06	2.2
F4E(78)	2413	72	48	1.36	2.3
F4E(78)	2414	72	13	.74	1.1
F4E(78)	2414	72	20	1.06	1.2
F4E(78)	2414	72	25	1.36	1.1
F4E(78)	2421	72	6	.74	.4
F4E(78)	2421	72	8	1.06	.4
F4E(78)	2421	72	11	1.36	.5

MDS	WORK CENTER	UE	MANNING	SORTIE RATE	MMH/S
F4E(78)	2422	72	12	.74	1.0
F4E(78)	2422	72	16	1.06	1.0
F4E(78)	2422	72	22	1.36	1.0
F4E(78)	2432	72	51	.74	4.5
F4E(78)	2432	72	74	1.06	4.6
F4E(78)	2432	72	97	1.36	4.5
F4E(78)	2434	72	6	.74	.4
F4E(78)	2434	72	7	1.06	.4
F4E(78)	2434	72	10	1.36	.5

RAND/R-2358/2-PA&E